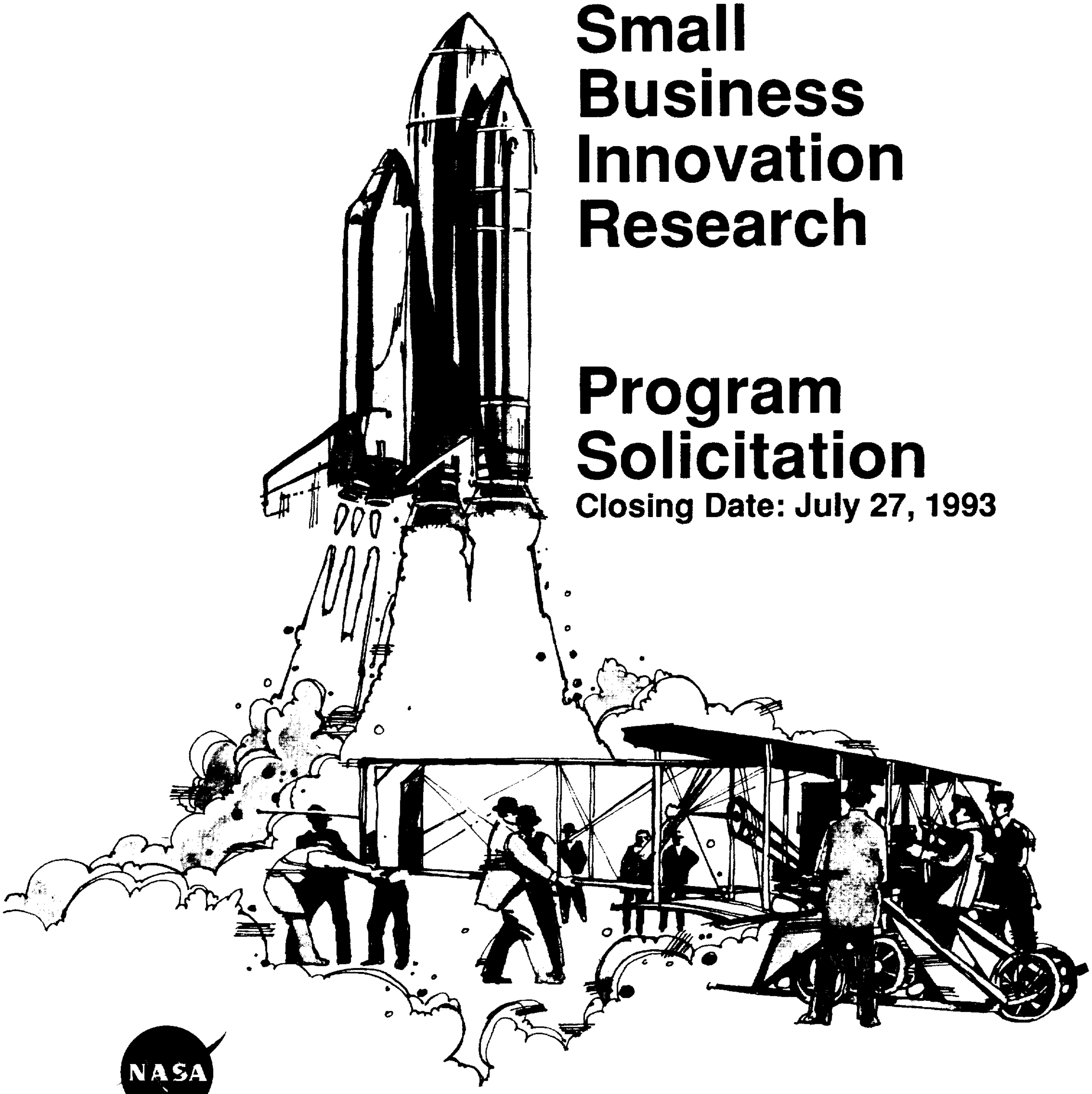
SBIR 93-1

# Small Business Innovation Research

# Program Solicitation

**Closing Date: July 27, 1993**



National Aeronautics and
Space Administration
Washington, DC 20546

# Important Considerations

## 1. Proposals must meet Solicitation requirements.

Please read this Solicitation carefully before developing a Phase I proposal. Verify that each proposal conforms to the requirements specified herein. Certain requirements and subtopics in the NASA 1993 Solicitation differ from those in previous years. Proposals that do not meet all of the requirements of this Solicitation may not be responsive and may not be evaluated. A check list of important requirements is provided on the inside rear cover.

## 2. Commercial application potential is important.

This is an evaluation and selection consideration in both Phase I and Phase II.

## 3. SBIR Solicitation requirements vary among federal agencies.

Proposals prepared for other agencies should not be submitted to NASA without modification to conform with all requirements of this Solicitation.

## 4. Information requests must be limited during the Solicitation period.

To insure competitive fairness, NASA Field Installations and Headquarters Offices cannot accept inquiries for interpretations of the technical subtopics or for advice on specific proposals during the Phase I Solicitation and proposal evaluation periods.

## 5. There are constraints on submitting proprietary information.

Provisions for including proprietary information in SBIR proposals are described in Section 5.4 of this Solicitation.

## 6. Mandatory eligibility requirements apply.

Eligibility requirements for small businesses and Principal Investigators are given in Section 1.4.

Contents of NASA SBIR 93-1 Program Solicitation

# National Aeronautics and Space Administration

# Small Business Innovation Research

# *1993 Program Solicitation*

## 1.0 Program Description

### 1.1 Introduction

The National Aeronautics and Space Administration (NASA) invites eligible small business concerns to submit Phase I proposals for its 1993 Small Business Innovation (SBIR) Program, which is described in this eleventh annual NASA SBIR Program Solicitation. The 1993 Solicitation period for Phase I proposals begins May 17, 1993 and ends at 4:30 p.m. EDT, July 27, 1993. Firms with research or research and development capabilities (R/R&D) in any of the listed topic and subtopic areas are encouraged to participate. This document contains program background information, outlines eligibility requirements for SBIR participants, describes the three SBIR program phases, and provides the information qualified offerors need to prepare and submit responsive proposals.

Through the SBIR Program NASA seeks innovative concepts from small business concerns addressing specified program needs, problems or opportunities described in the SBIR Solicitation subtopics. Offerors should note that the group of technical subtopics in which proposals are solicited is broad in scope but may not necessarily include all areas of current NASA activity. It should also be noted that in 1993 there is major new emphasis on selecting projects that also have commercial application potential.

NASA plans to select approximately 360 proposals during November, 1993 for negotiation of Phase I fixed-price contract awards. The Phase I performance period will be six months, and the contract awards will not exceed $70,000. NASA anticipates that during 1994 approximately half the successful Phase I projects from the 1993 program will be selected for Phase II development.

### 1.2 Program Features

**1.2.1 Legislative Basis.** The Solicitation is issued pursuant to the authority contained in 15 U.S.C. 638 (j)--P.L. 102-564, the Small Business Research and Development Act of 1992, amending the Small Business Innovation Development Act of 1982, 15 U.S.C. 638, P.L. 97-219 and P.L. 99-443. SBIR policy is provided by the Small Business Administration (SBA) Policy Directive for SBIR. The current revision became effective on January 26, 1993.

**1.2.2 Objectives.** SBIR program objectives established by law include stimulating technological innovation in the private sector, strengthening the role of small business concerns in meeting federal research and development needs, increasing the commercial application of federally supported research results, and fostering and encouraging participation by socially and economically disadvantaged persons and women-owned small businesses in technological innovation.

**1.2.3 Program Funding.** Participating agencies conduct SBIR programs by reserving a small percent of their extramural research and development budgets for funding agreements with small business concerns for R/R&D during the first two phases of the three-phase process described below; in 1993 the percentage is 1.5 percent. Each agency, at its sole discretion, selects the technical topics and subtopics included in its Solicitation, chooses its SBIR awardees, and may decide to make several awards or no awards under any subtopic. Phase III activities are funded by the private sector or by the government using non-SBIR funds.

**1.2.4 NASA Program Management.** The NASA SBIR program is an agency-wide effort that contributes to NASA's mission in planning, directing, and conducting civil research and development in space and aeronautics. All NASA Field Installations (Field Centers) and Headquarters Program Offices participate. The NASA Headquarters Office of Advanced Concepts and Technology provides overall management and direction of SBIR while the NASA Field Centers identify R&D needs, evaluate proposals, and manage the individual projects. The NASA installations that implement the program are:

- ARC: **Ames Research Center**, Moffett Field, California
- GSFC: **Goddard Space Flight Center**, Greenbelt, Maryland
- HQ: **NASA Headquarters**, Washington, DC
- JPL: **Jet Propulsion Laboratory**, Pasadena, California
- JSC: **Lyndon B. Johnson Space Center**, Houston, Texas
- KSC: **John F. Kennedy Space Center**, Florida
- LaRC: **Langley Research Center**, Hampton, Virginia
- LeRC: **Lewis Research Center**, Cleveland, Ohio
- MSFC: **George C. Marshall Space Flight Center**, Huntsville, Alabama
- SSC: **John C. Stennis Space Center**, Mississippi

## 1.3 Three-Phase SBIR Program

**1.3.1 Phase I.** The objectives of Phase I are (1) to establish the feasibility and merit of an innovative scientific or technical concept proposed in response to an opportunity or agency need stated in a subtopic of this Solicitation, and (2) to help determine the capabilities of new small businesses selected to participate in the program. Unsolicited proposals and those not responsive to a subtopic are not eligible for consideration in the SBIR program.

Projects may be experimental or theoretical in nature, but all must be directed toward development of products, processes, or techniques in support of NASA mission objectives. Projects are expected to emphasize near-term applicability to NASA (preferably 5 to 10 years) and also have direct or indirect commercial application potential.

The Phase I proposal must concentrate on means to establish the scientific or technical feasibility of the proposed innovation and to justify further NASA support in Phase II. It must conform to the format described in Section 3 of this Solicitation. Evaluation and selection criteria, which are described in Section 4.1, include scientific/technical merit, innovativeness and originality, value and priority to NASA, non-federal commercial application potential, qualifications of the firm and its ability to undertake the proposed project, and soundness of the workplan. NASA alone is responsible for all determinations.

Phase I funding agreements with NASA are fixed-price contracts. Simplified contract documentation is employed. In 1993, NASA funding for each Phase I contract is limited to $70,000. Approximately 360 selections will be made during November 1993.

Offerors should not submit proposals requiring substantial Phase I participation and involvement of NASA technical monitors. SBIR contractors are expected to have the capability for independent conduct of the R/R&D they propose. Successful offerors will have up to six months to complete their Phase I projects and submit their Phase I final reports and Phase II proposals.

**1.3.2 Phase II.** The objective of Phase II is to continue development of selected innovations shown feasible in Phase I that have the highest potential value to NASA and to the U.S. economy. Eligibility for NASA Phase II is limited to contractors conducting the NASA Phase I projects.

Phase II projects are chosen from competitive evaluations of Phase II proposals submitted at the end of Phase I. It is planned that in 1994 about half the successfully completed Phase I projects resulting from this 1993 Solicitation will be selected for Phase II continuations. Fixed-price contracts are usually employed in Phase II, with performance periods up to two years. Funding for each Phase II project selected in 1994 is expected to be limited to $600,000.

The Phase II proposal evaluation and selection criteria noted in Section 4.2 are similar to those for Phase I but include consideration of the results of Phase I. However, for Phase II there will be greater emphasis on evidence of commercial application potential than in Phase I, particularly for non-government uses. Also, proposed Phase II cost will be a significant consideration based on NASA's judgements of cost, value and reasonableness.

Phase II proposals are more comprehensive than those required for Phase I. They are prepared in accordance with instructions provided by the NASA Installations contracting Phase I. Phase I contractors competing for Phase II must meet the Phase II proposal schedule provided by the NASA Installation requesting Phase II proposals.

**1.3.3 Phase III.** Phase III objectives are (1) pursuit by SBIR contractors of commercial applications of their project results, using private sector funds, in support of the government's desire to stimulate technological innovation and provide for the national return on investment from government-funded R/R&D; and/or (2) further contracts with the government relative to the SBIR project.

The competition for Phase I and Phase II awards satisfies any competition requirement of the Competition in Contracting Act for subsequent Phase III contracting. NASA will give special acquisition preference for pursuing continued development or production developed under the SBIR program, including sole source awards to the small business performing the research if appropriate. SBIR funds may not be used for Phase III funding agreements.

The potential commercial applications in Phase III of the proposed SBIR project are evaluation and selection considerations in both Phases I and II.

## 1.4 Eligibility To Participate in SBIR

**1.4.1 Small Business Concern.** Only firms qualifying as small business concerns as defined in Section 2.2 of this Solicitation are eligible to participate in the SBIR program. SBIR eligibility does not require that the offeror qualify as a socially and economically disadvantaged small business (see Section 2.3) or as a women-owned small business (see Section 2.4).

**1.4.2 Place of Performance.** For both Phase I and II, the R/R&D must be performed in the United States (see Section 2.5) unless otherwise approved in writing by NASA.

**1.4.3 Principal Investigator.** The Principal Investigator (PI) is presumed to be key to the success of an SBIR project. The PI must have the technical competence and authority to plan and guide the proposed research and must make a substantial contribution to the project. The proposal must state the time and effort planned for the PI. Co-Principal Investigators are not acceptable, and substitution of a Principal Investigator at any time may be made only with NASA's written consent.

The primary employment of the Principal Investigator must be with the small business concern at the time of contract award and during the conduct of the research. Primary employment with the small business requires a minimum of 20 hours per week (average), and it precludes more than half-time employment with any other organization or more than half-time student status in an academic institution.

The offeror must state that the primary employment of the proposed PI will be with the small business concern during the conduct of the SBIR contract and explain the anticipated eligibility of a proposed PI who, at the time the proposal is submitted, has primary employment other than with the offeror. Such statements are required in both Phase I and Phase II proposals.

A person employed in any capacity by an academic institution may serve as a Principal Investigator only if the offeror provides a certification from the academic institution that primary employment of the PI with the small business concern during SBIR contract periods is acceptable to it and that it approves any required reduction of work-load and schedule required of the employee that would be needed to establish eligibility as the PI during the conduct of the SBIR contract.

## 1.5 General Information

**1.5.1 Means of Contacting NASA SBIR.**

**1) An electronic bulletin board system (BBS)** now provides access to SBIR documents stored in electronic ASCII format, including the latest copy of the Program Solicitation, participant award information, SBIR press releases, and program statistics.

The BBS provides bulletins of special interest, such as the current schedule for award announcements. Phase I awards will be listed the day that they are officially announced.

The BBS enables contact with the SBIR program office through the system's E-mail service. The bulletin board is monitored on a daily basis.

The SBIR BBS currently operates two lines at 2400 baud, no parity, 8 data bits and 1 stop bit. The phone numbers are:

| | |
|---|---|
| Washington, DC, local area: | 202-488-2939 |
| Nationwide toll free: | 800-547-1811 |

**2) Facsimile Machine.** Inquiries and requests for additional copies of the Solicitation may also be made through the NASA SBIR facsimile machine. The telephone number is 202-488-7838. Inquiries must include the name and telephone number of the person to contact, the organization name and address, and the specific questions or requests.

3) **Telephone Information Inquiries** may also be made using the NASA SBIR telephone number, 202-488-2940. Office hours are 8:00 am to 4:30 pm Eastern time Monday through Friday. Note: requests for documents should not be made by telephone.

4) **NASA SBIR General Information Contact.** Requests for general information about the NASA SBIR program should be addressed **in writing** to:

Mr. John A. Glaab
SBIR Program Manager
Code CR
National Aeronautics and Space Administration
Washington, DC 20546

**1.5.2 Questions About This Solicitation.** To ensure fairness, questions relating to the intent and content of subtopics and for advice on proposal writing can not be answered during the Phase I solicitation period ending July 27, 1993. Only questions requesting clarification of solicitation instructions and administrative matters will be answered.

**1.5.3 Questions Regarding Proposal Status.** Evaluation and selection of proposals for negotiation leading to contract award will require about three months after the Solicitation closes on July 27, 1993. Information about proposals status will not be available until final selections are announced except for the postcards mailed by NASA to confirm the receipt of proposals, as noted in Section 6.5 of this Solicitation.

**1.5.4 Technical Background Information.** The subtopic descriptions in Section 8 of this Solicitation include references to documents describing the background and status of the technology areas of interest. Section 7 lists sources of many of these references.

Numerous organizations, some of which are listed in this Solicitation, offer assistance to firms preparing SBIR proposals. NASA cannot accept responsibility for their independent interpretations of the intent or content of the subtopics and the requirements set forth in this Solicitation, or for proposal assistance they may provide to offerors.

## 1.6 Technical Topics and Subtopics

**1.6.1 NASA SBIR Topics.** Fifteen general technical topics are included in Section 8 of this Solicitation, as follows.

| | |
|---|---|
| 01.00 | Aeronautical Propulsion and Power |
| 02.00 | Aerodynamics and Acoustics |
| 03.00 | Aircraft Systems, Subsystems, and Operations |
| 04.00 | Materials and Structures |
| 05.00 | Teleoperators and Robotics |
| 06.00 | Computer Sciences and Applications |
| 07.00 | Information Systems and Data Handling |
| 08.00 | Instrumentation and Sensors |
| 09.00 | Spacecraft Systems and Subsystems |
| 10.00 | Space Power |
| 11.00 | Space Propulsion |
| 12.00 | Human Habitability and Biology in Space |
| 13.00 | Quality Assurance, Safety, and Check-Out for Ground and Space Operations |
| 14.00 | Satellite and Space Systems Communications |
| 15.00 | Materials Processing, Micro-Gravity, and Commercial Applications in Space |

Each of these topics is divided into subtopics that may vary from year to year. Subtopics are developed by project managers and researchers at all NASA Installations and reflect the Installations' needs and priorities. All subtopics are candidates for the selection of Phase I projects and there is no quota for selection in any subtopic.

**1.6.2 Multiple Proposal Submissions.** An offeror may submit any number of proposals to any number of subtopics, but every proposal submitted must be unique, must be limited in scope to just one subtopic, and may be submitted under only one subtopic. **Identical or substantially similar proposals submitted in response to this Solicitation will not be evaluated.** Should an innovation have relevance to more than one subtopic, the offeror must make the choice of a single subtopic under which to submit it.

# 2.0 Definitions

The following definitions apply for purposes of this Solicitation.

**2.1 Research or Research and Development (R/R&D):** Any activity that is (1) a systematic, intensive study directed toward greater knowledge or understanding of the subject studied, (2) a systematic study directed specifically toward applying new knowledge to meet a recognized need, or (3) a systematic application of knowledge toward the production of useful materials, devices, systems, or methods, including the design, development, and improvement of prototypes and new processes to meet specific requirements.

**2.2 Small Business Concern:** A business concern that, at the time of award of Phase I and Phase II funding agreements:

- Is independently owned and operated, is organized for profit, is not dominant in the field of operation in which it is proposing, and has its principal place of business located in the United States;

- Is at least 51 percent owned by, or, in the case of a publicly owned business, at least 51 percent of its voting stock is owned by United States citizens or lawfully admitted permanent resident aliens; and

- Has, including its affiliates, a number of employees not exceeding 500 and meets the other regulatory requirements found in 13 CFR Part 121. Business concerns, other than investment companies licensed, or state development companies qualifying under the Small Business Investment Act of 1958, 15 U.S.C. 661, et seq., are affiliates of one another when, either directly or indirectly, (1) one concern controls or has the power to control the other or (2) a third party controls or has the power to control both. Control can be exercised through common ownership, common management, and contractual relationships. The term "affiliates" is defined in greater detail in 13 CFR 121.3(a). The term "number of employees" is also defined in 13 CFR 121.2(b).

Small business concerns include sole proprietorships, partnerships, corporations, joint ventures, associations, or cooperatives. Eligible joint ventures are limited to no more than 49 percent participation by foreign business entities.

**2.3 Socially and Economically Disadvantaged Small Business Concern:** A small business concern that (1) is at least 51 percent owned by an Indian tribe or a native Hawaiian organization or by one or more individuals who are socially and economically disadvantaged and (2) has its management and daily business controlled by one or more such individuals.

Socially and economically disadvantaged individuals include members of any of the following groups: African Americans; Hispanic Americans; Native Americans (American Indians, Eskimos, Aleuts, and native Hawaiians); Asian-Pacific Americans; and subcontinent Asian Americans.

**2.4 Women-Owned Small Business:** A small business that is at least 51 percent owned by a woman or women who also control and operate it. In this context to "control" means to exercise the power to make policy decisions; to "operate" means to be actively involved in day-to-day management.

**2.5 United States:** The 50 states, the District of Columbia, the territories and possessions of the United States, the Commonwealth of Puerto Rico, the Commonwealth of the Northern Mariana Islands, and the Trust Territory of the Pacific Islands.

**2.6 Subcontract:** Any agreement, other than one involving an employer-employee relationship, entered into by a federal government contractor calling for supplies or services required solely for the performance of the original contract. See also Sections 3.5 Part 9 and 5.12 of this Solicitation.

**2.7 Innovation Research:** R/R&D on an innovation. Innovation in the context of the NASA SBIR program includes, but is not limited to, invention. Innovation encompasses new, original, and imaginative approaches to the solution of new and old problems; major improvements or advances to existing technology; exploitation of new technological opportunities; and some limited aspects of basic research when such objectives are stated in the technical subtopics.

Proposals for activities that do not require innovation as defined above are not acceptable in the SBIR program.

**2.8 Commercialization:** The process of developing markets and producing and delivering products for sale (whether by the originating party or by others); as used here, commercialization includes both government and non-government markets.

# 3.0 Phase I Proposal Content and Preparation

## 3.1 Proposal Instructions and Requirements

The purpose of an SBIR Phase I proposal is (1) to provide sufficient information to convince NASA that the proposed work represents a sound approach to investigating the feasibility of a valuable scientific or engineering innovation that is responsive to a Solicitation subtopic, and (2) to identify the eventual commercial application potential of the concept. A proposal should be self-contained and written with the care and thoroughness accorded papers for publication. Important considerations include the following:

**3.1.1** SBIR Phase I proposals must be limited to activities requiring significant scientific or technical innovation R/R&D, either experimental or theoretical. They may or may not involve construction and evaluation of a laboratory prototype. **Each project must develop specific end products or results** for delivery at the conclusion of the Phase II project. These may include data, hardware, or software programs. In every case a final report is required.

**3.1.2** Scientific or technical merit of the proposed innovation and its value to the NASA program are primary factors without which an award will not be made.

**3.1.3** Proposals directed toward systems studies, market research, commercial development of existing patents or products and concepts, and routine engineering design including straightforward modification to existing products or systems would be non-responsive to this Solicitation and would not be funded by SBIR.

**3.1.4** An SBIR proposal must respond to only one of the subtopics in Section 8 and must address a NASA program objective or opportunity described therein. The proposed innovation should also serve as the basis, directly or indirectly, for new commercial products, processes, or services that may benefit the general economy through the entrepreneurial activities of the small business concern.

## 3.2 General Requirements

**3.2.1 Page Limitation.** A Phase I SBIR proposal shall not exceed a total of 25 standard 8½ x 11 inch (21.6 x 27.9 cm) pages. All material submitted except any required listing of Phase II awards (See Section 3.7) will be included in the page count. Samples, videotapes, slides, or other ancillary items will not be accepted. **Proposals exceeding the 25 page limitation will be rejected without consideration.**

**3.2.2 Type Size.** No type size smaller than 10 point is to be used for text or tables, except as legends on reduced drawings. Pages are to be printed on one side only, and may be single or double spaced. Proposals prepared with smaller font sizes will be rejected without consideration.

**3.2.3 Brevity and Organization.** The proposal should be direct, concise, and logically organized. Offerors are requested not to use the entire 25-page allowance unless necessary.

**3.2.4 Content and Format.** All required items of information are to be covered fully and in the order set forth in Sections 3.3 to 3.7 of this Solicitation, but the space allocated to each will depend on the project chosen and the Principal Investigator's approach. Promotional and non-project-related material should not be included.

## 3.3 Required Format

The following format is required for all Phase I proposals. A Phase I proposal consists of a cover sheet, a project summary, a technical proposal, and a proposed budget. Each of these must be addressed in this order. **Each page shall be numbered consecutively at the bottom.** Detailed descriptions of all parts of the proposal follow.

## 3.4 Introductory Pages

**3.4.1 Page 1: Cover Sheet.** The offeror shall complete an original copy of the cover sheet, Form 9.A in this Solicitation, and sign it in ink. (Instructions are provided on the back of the form.) The offeror shall include a photocopy of the completed Form 9.A as page 1 of each copy of the proposal. (The original 9.A is submitted as a separate page; see Section 6.1.) No other cover sheet is permitted. The proposal title must be concise and descriptive of the proposed product or innovation. Avoid the use of acronyms in the title, and **do not use the subtopic title as the proposal title.**

**3.4.2 Page 2: Project Summary.** The offeror shall complete the project summary, Form 9.B (instructions are provided on the back of the form) as page 2 of the proposal. One copy is submitted as a separate page; see Section 6.1.

The technical abstract section shall include (1) the **specific proposed innovation** and how it addresses the stated subtopic requirement, (2) the project objectives, (3) the effort proposed, (4) the results anticipated, and (5) the expected NASA applications and benefits. Other information to be provided on the project summary includes potential commercial applications and key technical words for reference. The project summaries of all proposals enter the public domain; therefore offerors are advised not to include proprietary information in project summaries.

**3.4.3 Page 3: Table of Contents.** Page 3 of the proposal shall begin with a brief table of contents indicating the page numbers of each of the sections of the proposal.

## 3.5 Technical Proposal

The Technical Proposal shall consist of the following eleven parts.

**Part 1: Identification and Significance of the Innovation.** The first paragraph of the proposal shall contain (1) **a clear and succinct statement of the specific innovation proposed and why it is an innovation**, and (2) a brief explanation of how the innovation is relevant and important to meeting the need described in the subtopic. The paragraph shall contain no more than 150 words. **NASA reserves the right to reject proposals that lack this introductory paragraph.** Part 1 may also include appropriate background and elaboration to explain the proposed innovation.

**Part 2: Phase I Technical Objectives.** This shall include the specific objectives of the Phase I effort and state the technical questions the offeror must answer to determine the feasibility of the proposed innovation.

**Part 3: Phase I Work Plan.** The Phase I Work Plan must be complete and self-contained and shall include a detailed description of the proposed Phase I activities indicating what will be done and where the work will be carried out. The methods planned to achieve each objective or task should be discussed in detail. Schedules (Gantt charts, or other suitable scheduled task displays), task descriptions and assignments, resource allocations, and planned accomplishments including project milestones shall be included.

See Section 5.4.1 of this Solicitation regarding proprietary information. Offerors are advised to avoid including proprietary information if at all possible.

**Part 4: Related R/R&D and Bibliography of Related Work.** The purpose of Part 4 is to make clear the offeror's awareness of key recent developments by others in the specific subject area. It should include any significant R/R&D directly related to the proposal that was conducted by the offeror or Principal Investigator.

At the offeror's option, this section may include concise bibliographic references in support of the proposal if they are confined to activities directly related to the proposed work.

**Part 5: Relationship with Phase II or other Future R/R&D.** The offeror shall explain why the expected Phase I results would warrant Phase II continuation, and state the anticipated Phase II objectives. Any other planned R/R&D related to the proposed research should also be described.

**Part 6: Commercial Applications Potential.** The commercial potential of the proposed SBIR project is a significant proposal evaluation factor (see Section 4.1.2). Therefore, offerors will discuss in this section the potential direct or indirect commercial applications. Any requirements foreseen for Phase III activities needed to develop commercial applications shall also be noted. While commercial application (commercialization) is defined in the SBIR legislation as either government or private sector use, NASA is particularly interested in the private sector application potential and the offeror's intentions or plans to pursue it using non-government funding. Although well-developed plans may not be available at the time of the Phase I proposal, realistic assessments are needed to enable proposal evaluations to be made.

**Part 7: Company Information.** This shall provide information needed by evaluators to assess the ability of the firm to carry out the proposed Phase I and projected Phase II activities and the support of national SBIR objectives. While extensive corporate background or experience is not a prerequisite for an SBIR award, the capability of the offeror to perform the proposed research must be indicated.

A description of the firm's business organization, operations, R/R&D capabilities, and experience is to be provided, as well as a description of the firm's physical facilities including any instrumentation and equipment pertinent to the proposed research. If facilities, equipment, and instrumentation needed for the proposed research are not presently available, the offeror must explain how they are to be obtained. As a general rule, NASA will not fund the acquisition of equipment, instrumentation, or facilities under SBIR Phase I contracts.

**Part 8: Key Personnel.** The offeror shall identify the key employees to be committed to Phase I activities. Key personnel are the Principal Investigator and other individuals whose expertise is essential to the success of the project. Information on their education, experience, and any directly related publications is required. Offerors are requested to avoid extensive vitae and publication lists not pertinent to the proposed research.

This section shall also establish the Principal Investigator's eligibility (see Section 1.4.3 of this Solicitation) and indicate the extent to which (1) other proposals recently submitted or planned for submission in 1993 and (2) existing projects commit the PI's time concurrently with this proposed activity.

**Part 9: Subcontracts and Consultants.** Up to one-third of the research and/or analytical effort in Phase I may be conducted under subcontract to other firms, nonprofit organizations, and individual consultants (see Section 5.12 of this Solicitation). Subcontracting is encouraged when it permits the firm to conduct more valuable research or improve the prospects for commercial success.

The offeror must describe any proposed subcontracting and identify the organizations and individuals with whom subcontracts are planned. Generally, these arrangements will be viewed as key to the success of the work, so the expertise to be subcontracted must be described in detail as well as the functions, services, number of hours and labor rates, and extent of effort to be provided.

The proposal must include an agreement by each subcontracting organization and individual consultant that they will be available at the times required for the purposes and extent of effort described in the proposal.

**Part 10: Related Proposals to and Awards from Other Agencies.** If the offeror (1) has received federal government awards for related work, or (2) has submitted currently active proposals for similar work under other federal government program solicitations, or (3) intends to submit proposals for such work to other agencies during 1993, those awards, proposals and intentions must be identified. For all such awards and for active or intended proposals in 1993 the following information is required in Part 10:

(1) The agencies to which proposals have been or will be submitted or from which awards have been received.

(2) Date of proposal submission or date of award.

(3) Solicitation numbers under which proposals have been or will be submitted or awards received.

(4) The specific research topic for each proposal submitted or award received.

(5) Titles of research projects.

(6) Name and title of the Principal Investigator for each proposal that has been or will be submitted or award received.

**If no such awards have been received or no proposals have been submitted or are intended, the offeror shall so state.**

**Part 11: Previous NASA SBIR Awards Received.** Offerors who have received previous NASA SBIR awards shall list them showing contract numbers, the year of award, Phase I or II, the NASA Installations making the award, and project titles. If no NASA awards have been received, the offeror shall so state.

## 3.6 Proposed Budget

**3.6.1 Summary Budget.** Following the instructions on the back of the form, offerors shall complete Form 9.C, SBIR Summary Budget, and include it (and any budget explanation sheets, if needed) as the last page(s) of the proposal. Items on Form 9.C that do not apply to the proposed project may be omitted. Enough information shall be submitted to reveal how the offeror plans to use the requested funds and to enable NASA to determine whether the proposed budget is realistic and cost-effective. Special attention is directed to the following items:

**3.6.2 Property.** NASA will not normally fund instrumentation, equipment, or facility acquisition under Phase I. However, any purchases of products under an SBIR contract using NASA funds should be only American-made to the extent possible.

**3.6.3 Travel.** Budget requests for travel funds are not normally acceptable for Phase I.

**3.6.4 Profit.** A profit or fee may be included in the proposed budget as noted in Solicitation Section 5.9.

**3.6.5 Cost Sharing.** See Section 5.8.

## 3.7 Addendum for Prior SBIR Phase II

Offerors who have received more than 15 Phase II awards from all agencies since October 1, 1987, are required to report them and their progress toward commercialization. Awards shall be listed in a separate "Addendum: Phase II History" that will not be counted against the Phase I 25-page proposal limit. Information for each Phase II contract shall include:

Name of awarding agency
Date of award and date of completion
Funding agreement number and amount
Topic or subtopic name
Project title

Sources, dates and amounts of federal and/or private sector Phase III follow-on funding agreements

Post-Phase II commercialization activities, including sales and projections

## 3.8 Check List

The Check List on the inside back cover of this Solicitation is provided to assist the offeror in preparing a responsive proposal. It should not be submitted with the proposal.

# 4.0 Method of Evaluation and Evaluation Criteria

## 4.1 Phase I

**4.1.1 Evaluation Process.**Proposals are first screened for compliance with administrative requirements of the Solicitation. Those that pass are then reviewed to determine whether they respond to the subtopic chosen by the offeror. Those found to be responsive are evaluated in greater depth by two or more scientists and engineers at the NASA Installation responsible for the research, using the criteria listed under Section 4.1.2. Other NASA Installations may also conduct evaluations and make recommendations for selections of any proposals accepted for evaluation.

Evaluators base their conclusions only on information contained in the proposals. Offerors should not assume that evaluators are acquainted with the firm or key individuals or with any experiments or other information that has not been published in refereed professional journals or equivalent sources. Any pertinent references should be noted in Part 4 of the technical proposal; however, such references may or may not be considered by the evaluators.

**4.1.2 Phase I Evaluation Criteria.** Each proposal is judged and scored on its own merits using the uniform scoring procedure described below. The maximum possible percentage of the total score is indicated for each element described below.

**4.1.2.1 Scientific/technical merit** of the proposed innovation and its relevance to the needs stated in the selected subtopic, and the proposal's objectives and approach for addressing questions of feasibility. Innovativeness and originality are essential. **(40 percent.)**

**4.1.2.2 Anticipated commercial applications of the technology** and benefits to the U. S. economy. Applications include both federally funded and private-sector marketplace applications. **(25 percent.)**

**4.1.2.3 Qualifications** of the principal investigator, other key staff, consultants and subcontractors, if any, and the adequacy of available or obtainable instrumentation and facilities for the project. **(25 percent.)**

**4.1.2.4 Soundness** of the proposed work plan, budget, and schedule for meeting the Phase I objective of establishing the feasibility and merit of the proposed innovation as a basis for Phase II continuation. **(10 percent.)**

**4.1.3 Selection Process.** After a proposal is scored, it is ranked relative to all others evaluated under the same subtopic. Those considered suitable for selection are recommended for further consideration by the NASA Field Installation SBIR Committee. The Committee prepares final recommendations for selection in priority order, based on proposal merit, program balance, and Installation needs. These recommendations are then forwarded to NASA Headquarters for final selection decisions that take into consideration the recommendations from all Installations and overall NASA priorities and program balance.

## 4.2 Phase II

Phase II is initiated by a request for proposals issued by the NASA Installation awarding the Phase I contract. Such requests are issued solely to Phase I contractors whose progress is deemed to be satisfactory and where NASA is interested in Phase II continuation. These requests contain Phase II proposal preparation information, submission instructions, evaluation and award criteria, and a due date for response. Phase II proposals are submitted concurrently with the Phase I final report.

**4.2.1 Evaluation and Selection.** The NASA Installations responsible for the Phase I research comprehensively evaluate all Phase II proposals using uniform procedures and the criteria noted in Section 4.2.2. The Installation SBIR Committees then rank the proposals, taking into consideration overall quality, Phase III potential, value to NASA, and Installation program balance. The committees then forward their recommendations to the NASA Headquarters SBIR Office. Final selection consideration takes into account additional assessments made by Headquarters Program Offices of overall value to NASA, commercial application potential, and program balance.

**4.2.2 Phase II Evaluation Criteria.** A complete discussion of evaluation criteria for Phase II proposals will be provided with the Phase II request for proposal instruction. They are expected to include the following:

**4.2.2.1 Scientific/technical merit** and feasibility of the proposed R&D, with special emphasis on its innovativeness, originality, and technical payoff potential if successful.

**4.2.2.2 Results of Phase I,** including the degree to which Phase I objectives were met, the feasibility of the innovation, and whether the Phase I results indicate a Phase II project is appropriate.

**4.2.2.3 Future importance and eventual value** of the product, process, or technology results to the NASA mission.

**4.2.2.4 Capability of the Small Business Concern.** NASA will assess the capability of the concern to conduct Phase II based on (a) the validity of the project plans for achieving the stated goals, (b) the qualifications and ability of the project team (Principal Investigator, company staff, consultants and subcontractors) relative to the proposed research, and (c) the availability of any required equipment and facilities.

**4.2.2.5 Evidence of Commercial Potential.** Current SBIR legislation requires that consideration will be given to any or all of the following indications of commercial potential: (a) the small business concern's record of commercializing SBIR or other research, (b) the existence of funding commitments from private-sector or non-SBIR funding sources to help support Phase II, (c) the existence of non-federal follow-on commitments for pursuing Phase III activities, and (d) any other available indicators of commercial potential and the offeror's intent to pursue commercialization.

**4.2.3. Non-Federal Funding Support Commitments.** Offerors for Phase II contracts are strongly urged to obtain valid non-federal funding support commitments for (1) Phase III follow-on activities and (2) additional support of Phase II from parties other than the proposing firm. Valid funding support commitments must provide that a specific, substantial amount will be made available to the firm to pursue the stated Phase II and III objectives. They must indicate the source, date, and conditions or contingencies under which the funds will be made available. Alternatively, self-commitments of the same type and magnitude that are required from outside sources can be considered.

Funding support commitments from outside parties must be provided in writing to the proposing firms. They should accompany the Phase II proposal, but may be submitted until final Phase II selection decisions have been made by NASA. Mere expressions of technical interest by such parties in the Phase II research or of potential future financial support are not valid support commitments and will not be accepted as such by NASA.

## 4.3 Debriefing of Unsuccessful Offerors

After final Phase I and Phase II selection decisions have been announced, a proposal critique (debriefing) for an unsuccessful offeror may be provided to the offeror's corporate official or their designee. Only written requests are acceptable; telephone requests for debriefings will not be accepted. Debriefings are not opportunities to reopen selection decisions. They are intended to acquaint the offeror with perceived strengths and weaknesses of the proposal and perhaps identify constructive future action by the offeror.

Debriefings will not disclose the identity of the proposal evaluators nor provide proposal scores, proposal rankings in the competition, or the content of and comparisons with other proposals with which they were in competition.

**4.3.1 Phase I.** For Phase I proposals, all requests for debriefing must be directed in writing to the SBIR Program Manager, NASA Headquarters, **within 45 days after notification has been mailed to the offeror** that its proposal was not selected for award. Late requests will not be honored.

**4.3.2 Phase II.** To request debriefings on Phase II proposals, offerors must write the Contracting Officer at the NASA Installation **within 45 days after notification has been mailed to the offeror** that its proposal was not selected for award. Late requests will not be honored.

# 5.0 Considerations

## 5.1 Awards

Both Phase I and Phase II awards are subject to availability of funds. NASA has no obligation to make any specific number of Phase I or Phase II awards based on this Solicitation, and may elect to make several or no awards in any specific technical topic or subtopic.

In November 1993, NASA expects to announce the selection of approximately 360 proposals for negotiation of fixed-price Phase I contracts with values not exceeding $70,000. Following contract negotiations and awards, Phase I contractors will have six months to carry out their proposed Phase I programs unless otherwise approved by NASA.

NASA anticipates that during 1994 approximately 50 percent of the successfully completed Phase I projects resulting from this Solicitation will be selected for Phase II continuations based on the results of Phase I activities and competitive evaluations of Phase II proposals. Phase II funding agreements are usually fixed-price contracts with performance periods not exceeding 24 months and funding not exceeding $600,000.

## 5.2 Final Reports

Six (original plus five) copies of a final report on the Phase I project must be submitted to NASA upon completion of the Phase I research effort. The report shall be in accordance with Phase I contract provisions and shall elaborate the project objectives, work carried out, results obtained, and assessments of technical feasibility. Rights to this data shall be in accordance with the policies set forth in Section 5.5. of this Solicitation.

The final report shall include a single page project summary as the first page, on a form to be provided by NASA for that purpose, identifying the purpose of the research, a brief description of the research carried out, the research findings or results including the degree to which the Phase I objectives were achieved, and whether the results justify Phase II continuation. The potential applications of the project results in Phase III both for NASA purposes and for commercial purposes will also be included. The project summary is to be submitted without restriction for NASA publication.

To avoid duplication of effort, language used in the Phase I report may be used verbatim in the Phase II proposal.

## 5.3 Payment Schedule

Payments on Phase I contracts may be invoiced as follows: one-third at the time of award, one-third at project mid-point after award, and the remainder upon acceptance of the final report by NASA. The first two payments will be made 30 days after receipt of valid invoices. The final payment will be made 30 days after acceptance of the final report and other deliverables as required by the contract.

## 5.4 Treatment and Protection of Proposal Information

In the evaluation and handling of proposals, NASA will make every effort to protect the confidentiality of the proposals and their evaluations.

**5.4.1 Proprietary Information.** It is NASA policy to use information (data) included in proposals for evaluation purposes only and to protect such information from unauthorized use or disclosure. While this policy does not require that the proposal bear a notice, protection can be assured only to the extent that an appropriate "Notice", as described in the 1993 *SBA Policy Directive*, is applied to the data which constitute trade secrets or other information that is commercial or financial and confidential or privileged, as follows:

> "For any purpose other than to evaluate the proposal, this data shall not be disclosed outside the government and shall not be duplicated, used, or disclosed in whole or in part, provided that if a funding agreement is awarded to the proposer as a result of or in connection with the submission of this data, the Government shall have the right to duplicate, use or disclose the data to the extent provided in the funding agreement. This restriction does not limit the Government's right to use information contained in the data if it is obtained from another source without restriction. The data subject to this restriction are contained in pages ______ of this proposal."

It is recommended that offerors not include proprietary information in their proposals, but if included, the pages containing proprietary material shall be marked "Confidential proprietary material."

Other information will be afforded protection to the extent permitted by law, but NASA assumes no liability for use and disclosure of information to which the notice and legend have not been appropriately applied.

The offerer should also note that the above notice has been printed on the proposal cover page so that the offerer can alert NASA to the presence of pages containing proprietary material. **Do not label the entire proposal proprietary.**

**5.4.2 Non–NASA Reviewers.** In addition to government personnel, NASA, at its discretion and in accordance with 18-15.413-2 of the NASA FAR Supplement, may utilize scientists and engineers from outside the government in the proposal review process. Any decision to obtain outside evaluation shall take into consideration requirements for the avoidance of organizational or personal conflicts of interest and the competitive relationship, if any, between the prospective contractor or subcontractor(s) and the prospective outside evaluator. Any such evaluation will be under agreement with the evaluator that the information (data) contained in the proposal will be used only for evaluation purposes and will not be further disclosed.

**5.4.3 Release of Proposal Information.** By submission of a proposal, the offeror agrees to permit the government to disclose publicly the information contained in Forms 9.A and 9.B. Other proposal information (data) is considered to be the property of the offeror, and NASA will protect it from public disclosure to the extent permitted by law.

**5.4.4 Final Disposition of Proposals.** The government retains ownership of the copies of proposals accepted for evaluation, and they will not be returned to the offeror. Copies of all evaluated Phase I proposals will be retained for one year after the Phase I selections have been made, after which time unsuccessful proposals may be destroyed.

## 5.5 Rights in Data Developed Under SBIR Contracts

Rights to data used in, or first produced under, any Phase I or Phase II contract are specified in the clause at FAR 52.227-20, Rights in Data--SBIR Program. The clause provides for rights consistent with the following:

**5.5.1** Some data of a general nature are to be furnished to NASA without restriction (i.e., with unlimited rights) and may be published by NASA. These data will normally be limited to the project summary accompanying any periodic progress reports and the final report required to be submitted (see Section 5.2) but, in any event, the requirement for them will be specifically set forth in any contract resulting from this solicitation.

**5.5.2** In keeping with NASA's policy, data that constitute trade secrets or other information that is commercial or financial and confidential or privileged **and first developed at private expense** will not normally be acquired, but if acquired will be with "limited rights" or "restricted rights." Such rights do not include the right to use the data for manufacturing or re-procurement purposes.

**5.5.3** Other than as required by Section 5.5.1, rights in technical data including software developed under the terms of any funding agreement shall remain the property of the contractor, except that the government shall have the limited right to use such data for government purposes and shall not release such data outside the government without permission of the contractor for a period of four years from completion of the project from which the data were generated. However, effective at the conclusion of the four year period, the government shall retain a royalty-free license for government use of any technical data delivered under an SBIR contract whether patented or not, but (except per Section 5.5.2 above) is relieved of all disclosure prohibitions and assumes no liability for unauthorized use of the data by third parties.

## 5.6 Copyrights

Contractors will be permitted (in accordance with paragraph (c) of the clause at FAR 52.227-20) to assert or establish claim to copyright data first produced under a Phase I or Phase II contract, subject to a paid-up, nonexclusive, irrevocable, worldwide license for governmental purposes. The contractor is required to include an appropriate credit line acknowledging government support for any works published under copyrights.

## 5.7 Patents

The contractor will, as provided in the clause at FAR 52.227-11, Patent Rights-Retention by Contractor (Short Form), have first option to retain title to inventions made in the performance of any Phase I or Phase II contract in accordance with P.L. 96-517 (35 U.S.C. 200, et. seq.). This option is subject to the reservations and limitations, including a nonexclusive, royalty-free, irrevocable license in the Government and certain march-in rights to assure commercialization, as required by 35 U.S.C. 203 and implementing regulations thereunder.

Whenever an invention is made and reported under any NASA contract, it is NASA policy to withhold such report from disclosure to the public and to use reasonable efforts to withhold other information that may disclose the invention (provided that NASA is notified of the information and the invention to which it relates) for a reasonable time to allow the contractor to obtain patent protection as authorized by 35 U.S.C. 205.

## 5.8 Cost Sharing

Cost sharing is permitted for proposals under this Program Solicitation. However, cost sharing is not required, nor will it be a factor in proposal evaluation. If included, cost sharing should be shown in the summary budget but not included in items labeled "AMOUNT REQUESTED."

## 5.9 Profit or Fee

Both Phase I and Phase II SBIR contracts may include a reasonable profit or fee. The reasonableness of a proposed profit is examined by the Contracting Officers during contract negotiations; their determination is based on a variety of factors.

## 5.10 Joint Ventures and Limited Partnerships

Both joint ventures and limited partnerships are permitted, provided the entity created qualifies as a small business concern in accordance with the definition in Section 2.2. A statement of how the workload will be distributed, managed, and costed should be included in the proposal. A copy or comprehensive summary of the joint venture agreement or partnership agreement should be included.

## 5.11 Similar Proposals and Prior Work

If an award is made pursuant to a proposal submitted under this Program Solicitation, the firm will be required to certify that it has not previously been paid nor is currently being paid for essentially equivalent work by any agency of the federal government.

Submission of related proposals to and receipt of related awards from other agencies, intentions to submit related proposals during 1993 to other federal agencies, and prior NASA SBIR awards received by the offeror must be identified in the Technical Proposal Parts 10 and 11 as noted in Section 3.3 of this Solicitation.

## 5.12 Limits on Subcontracting Research and Analytical Work

Subcontracts (defined in Section 2.6 of this Solicitation) may be placed with other firms, universities and other non-profit organizations, and individual consultants, but there are cost limits on subcontracting the research and analytical portions of both Phase I and Phase II contracts:

**5.12.1** For Phase I, a minimum of two-thirds of the dollar amount of the research and/or analytical effort must be performed by the proposing small business concern unless otherwise approved in writing by the contracting officer.

**5.12.2** For Phase II, a minimum of one-half of the dollar amount of the research and/or analytical effort must be performed by the proposing small business concern unless approved in writing by the contracting officer.

**NOTE: The dollar amounts of research and analytical effort is the total proposal cost without fee or profit.**

## 5.13 Contractor Commitments

Upon award of a contract, the contractor will be required to make certain legal commitments through acceptance of numerous clauses in the Phase I contract. The outline that follows illustrates the types of clauses that will be included in the Phase I contract. This is not a complete list of clauses to be included in Phase I contracts, nor does it contain specific wording of these clauses. Copies of complete provisions will be made available prior to contract negotiations.

**5.13.1 Standards of Work.** Work performed under the contract must conform to high professional standards. Analyses, equipment, and components for use by NASA will require special consideration to satisfy the stringent safety and reliability requirements imposed in aerospace applications.

**5.13.2 Inspection.** Work performed under the contract is subject to government inspection and evaluation at all reasonable times.

**5.13.3 Examination of Records.** The Comptroller General (or a duly authorized representative) shall have the right to examine any directly pertinent records of the contractor involving transactions related to the contract.

**5.13.4 Default.** The government may terminate the contract if the contractor fails to perform the contracted work.

**5.13.5 Termination for Convenience.** The contract may be terminated by the government at any time if it deems termination to be in its best interest, in which case the contractor will be compensated for work performed and for reasonable termination costs.

**5.13.6 Disputes.** Any dispute concerning the contract that cannot be resolved by mutual agreement shall be decided by the contracting officer with right of appeal.

**5.13.7 Contract Work Hours.** The contractor may not require a non-exempt employee to work more than 40 hours in a work week unless the employee is paid for overtime.

**5.13.8 Equal Opportunity.** The contractor will not discriminate against any employee or applicant for employment because of race, color, religion, age, sex, or national origin.

**5.13.9 Affirmative Action for Veterans.** The contractor will not discriminate against any employee or applicant for employment because he or she is a disabled veteran or veteran of the Vietnam era.

**5.13.10 Affirmative Action for Handicapped.** The contractor will not discriminate against any employee or applicant for employment because he or she is physically or mentally handicapped.

**5.13.11 Officials Not to Benefit.** No member of or delegate to Congress shall benefit from the SBIR contract.

**5.13.12 Covenant Against Contingent Fees.** No person or agency has been employed to solicit or secure the contract upon an understanding for compensation except bona fide employees or commercial agencies maintained by the contractor for the purpose of securing business.

**5.13.13 Gratuities.** The contract may be terminated by the government if any gratuities have been offered to any representative of the government to secure the contract.

**5.13.14 Patent Infringement.** The contractor shall report to NASA each notice or claim of patent infringement based on the performance of the contract.

**5.13.15 American-Made Equipment and Products.** Equipment or products purchased under an SBIR contract must be American-made whenever possible.

## 5.14 Additional Information

**5.14.1 Precedence of Contract over Solicitation.** This Program Solicitation reflects current planning. If there is any inconsistency between the information contained herein and the terms of any resulting SBIR contract, the terms of the contract are controlling.

**5.14.2 Evidence of Contractor Responsibility.** Before award of an SBIR contract, the Government may request the offeror to submit certain organizational, management, personnel, and financial information to establish responsibility of the offeror.

**5.14.3 Limitations on Awards.** This Solicitation is not an offer by the Government to make any specific number of awards under either Phase I or Phase II. NASA is not responsible for any monies expended by the offeror before award of any contract resulting from this Solicitation. Also, awards under this Program Solicitation 93-1 are contingent upon the availability of funds.

**5.14.4 Classified Proposals.** NASA will not accept classified proposals.

**5.14.5 Unsolicited Proposals.** Unsolicited proposals will not be accepted under the SBIR program in either Phase I or Phase II.

# 6.0 Submission of Proposals

## 6.1 What to Send

Offerors must submit the following items for each proposal:

**6.1.1 The original proposal cover sheet signed in ink and included as a separate page.** This is Form 9.A of this Solicitation.

**6.1.2 One project summary as a separate sheet.** This is Form 9.B of this Solicitation.

DO NOT STAPLE THE ABOVE ITEMS TOGETHER: LEAVE SEPARATE.

**6.1.3 Five copies of the entire proposal as described in Sections 3.3 through 3.7.** Each proposal copy is to be stapled separately.

## 6.2 Physical Packaging Requirements

**6.2.1 Bindings.** Do not use bindings or special covers. Staple the pages of each copy of the proposal in the upper left-hand corner only.

**6.2.2 Packaging.** Secure packaging is mandatory. NASA cannot process proposals damaged in transit.

All items (6.1.1 through 6.1.4) for any proposal must be sent in the same package. If more than one proposal is being submitted, it is requested that all proposals be sent in the same package.

**DO NOT SEND DUPLICATE SETS of any proposal as "insurance" that they will be received.**

## 6.3 Where to Send Proposals

All proposals that are mailed through the U.S. Postal Service by first class, registered, or certified mail are to be sent to NASA Headquarters, addressed as follows:

SBIR Program Manager
Mail Code CR
National Aeronautics and Space Administration
Washington, DC 20546

Proposals sent by express mail or commercial delivery services (e.g. Federal Express) or handcarried are to be delivered to the following address between the hours of 8 AM and 4:30 PM.:

SBIR Proposal Receiving Station
250 E Street, S.W., Suite 380
Washington, DC 20024

The following telephone number may be used when required for reference by delivery services: 202-488-2940. **NASA cannot receive proposals on Saturdays, Sundays, or federal holidays.**

## 6.4 Deadline for Proposal Receipt

**Deadline for receipt of Phase I proposals at NASA is 4:30 p.m. EDT on Tuesday, July 27, 1993. Any proposal received after that date and time will be considered late unless it was sent by the U.S. Postal Service's registered or certified mail not later than July 22, 1993.** Since the postmark will be the evidence on which the decision is made, it is incumbent on offerors to assure themselves that the postmark is clear and easily legible; hand cancellation is suggested. Postage meter date stamps are not acceptable. All other methods of proposal delivery will be considered late if they are received after the deadline of 4:30 pm EDT on July 27, 1993. Proposals may not be submitted by facsimile. **Late proposals will not be eligible for award and will be rejected without a review.**

## 6.5 Acknowledgement of Proposal Receipt

NASA will acknowledge receipt of proposals by a postal card mailed to the company official who endorsed the proposal cover sheet. If a proposal acknowledgement card is not received from NASA within 30 days following the closing date of this Solicitation, the offeror should call the SBIR inquiry number, 202-488-2940. NASA will not respond to such inquiries made prior to August 26, 1993.

## 6.6 Withdrawal of Proposals

Proposals may be withdrawn by written notice or telegram (including mailgram) received at any time before award. Proposals may be withdrawn in person by an offeror or an authorized representative, if the representative's identity is made known and the representative signs a receipt for the proposal.

# 7.0 Scientific and Technical Information Sources

## 7.1 Technical References

To assist offerors in obtaining technical information about the subtopics, most of the Subtopic descriptions include selected references. These documents are in the public domain and are available from the public information sources cited below and from university technical libraries and larger public libraries. **Please do not request any of these reference documents from the SBIR Office or from NASA Installations.**

To help proposers gain access to the documents cited, the references include the document accession numbers or the initials of the agency from which it is available. These are described below.

*Citation:* AIAA or (Ann-nnnnn)
American Institute of Aeronautics and Astronautics
Attn: Library
555 West 57th Street, Suite 1200
New York, NY 10019
Tel: 212-247-6500 ext.231

*Citation:* CASI or (Nnn-nnnnn) or (Xnn-nnnnn)
NASA Center for AeroSpace Information
800 Elkridge Landing Road
Linthicum Heights, MD 21090
Tel: 301-621-0100
410-859-5300

*Citation:* DTIC
Defense Technical Information Center
Cameron Station
Alexandria, VA 22304-6145
Tel: 703-274-6800

*Citation:* EI or ESL
Engineering Societies Library
345 East 47th Street
New York, NY 10017
Tel: 212-705-7611

*Citation:* INSPEC or IEEE
IEEE Service Center
PO Box 1331 445 Hoes Lane
Piscataway, NJ 08855-1331
Tel: 908-981-0060

*Citation:* NTIS or (PBnn-nnnnn/XAB)
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Title ID#: 703-487-4780
Fax: 703-321-8547

*Citation:* UMI
University Microfilms International
300 North Zeeb Road
Ann Arbor, MI 48106-1346
Tel: 800-521-0600
Tel: 313-761-4700 MI

Some items have only an identification number with one of the following prefixes.

*Citation:* ISBN
The International Standard Book Number may be used to order from the publisher or as an identification to library borrowing.

*Citation:* ISSN
The International Standard Serial Number may be used to identify a journal or periodical in which the article is published.

*Citation:* LCCN
The Library of Congress Control Number may be used to identify an item available at the Library of Congress.

The accession numbers are also used in the NASA Scientific and Technical Information System. This is NASA's large database that is the foundation of RECON, the on-line bibliographic search system maintained by NASA's Center for Aerospace Information (CASI), formerly the NASA Scientific and Technical Information Facility. (See citation above.)

Some documents are subject to restricted distribution regulations. If applicable, these restrictions are noted in the reference either in words or with the following acronyms:
EAR: Export Administration Regulations
ITAR: International Traffic in Arms Regulations

Any firm can, for a fee, use the services of one of the NASA Regional Technology Transfer Centers to utilize the NASA database and many others. Full-text paper copies or microfiche of almost all reports and papers in the databases are available.

Technical libraries having access to RECON may request reports directly from CASI. Current NASA contractors may, for a fee, register to use the NASA RECON system. Contact CASI at 301-621-0100.

## 7.2 Regional Technology Transfer Centers

NASA's network of Regional Technology Transfer Centers (RTTCs), listed below, provides a variety of services to NASA SBIR offerors, including searches of the Scientific and Technical Information System, the database containing many of the references cited in Section 8. RTTCs should be contacted directly to determine whether additional services are available and to discuss fees charged since these vary, depending upon the organization and type of service requested.

**Northeast:**
Center for Technology Commercialization
Massachusetts Technology Park
100 North Drive
Westborough, MA 01581
Tel: 508-870-0042

**Mid-Atlantic:**
Mid-Atlantic Technology Applications Center
University of Pittsburgh
823 William Pitt Union
Pittsburgh, PA 15260
Tel: 412-648-7000

**Southeast:**
Southern Technology Applications Center

University of Florida, College of Engineering
Box 24, One Progress Boulevard
Alachua, FL 32615
Tel: 904-462-3913
800-354-4832 FL only
800-225-0308 outside FL

**Mid-West:**
Great Lakes Technology Transfer Center
Battelle Memorial Institute
25000 Great Northern Corporate Center, #450
Cleveland, OH 44070-5310
Tel: 216-734-0094

**Mid-Continent:**
Mid-Continent Technology Transfer Center
Texas Engineering Experiment Station
The Texas A&M University System
237 Wisenbaker Engineering Research Center
College Station, TX 77843-3401
Tel: 409-845-8762

**Far-West:**
Far-West Regional Technology Transfer Center
University of Southern California
3716 South Hope Street, Suite 200
Los Angeles, CA 90007-4344
Tel: 213-743-6132
800-642-2872 CA only
800-872-7477 outside CA

The following **Technology Application Center** provides services on a nation-wide basis to those interested in Earth-observing technologies, including image-processing and geographic information systems.

Technology Application Center
University of New Mexico
2500 Yale, S.E., Suite 100
Albuquerque, NM 87131
Tel: 505-277-3622

## 7.3 National Technical Information Service

The **National Technical Information Service,** an agency of the Department of Commerce, is the federal government's central clearinghouse for publicly funded scientific and technical information. For information about their various services and fees, call or write:

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Tel: 703-487-4600
Fax: 703-321-8647

One service is on-line access to abstracts of SBIR awards from all agencies through the Federal Research in Progress (FEDRIP) database. FEDRIP is accessible through DIALOG, a private information service. For a free copy of the FEDRIP Search Guide, phone 703-487-4650 and ask for PR 847.

# 8.0 Technical Topics and Subtopics

Section 8 contains detailed descriptions of the technical areas (subtopics) within which small business concerns are invited to submit proposals.

Each subtopic description in Section 8 outlines the technical problem for which NASA requests proposals for innovative R&D solutions. Most subtopics also include references to documents in the public domain describing the background or status of relevant technologies. Ways to access these references are described in Section 7.

# 9.0 Forms

One copy of each of the four forms needed to complete a proposal are included in this Solicitation document:
Form 9.A - Proposal Cover
Form 9.B - Project Summary
Form 9.C - Proposal Summary Budget

Offerors should photocopy them as needed.

A Proposal Checklist is also included on the inside back cover for the offeror's use. It should not be submitted with the proposal.

## Listing of Technical Topics and Subtopics

# Technical Topics and Subtopics

## 01.00 Aeronautical Propulsion and Power

### 01.01 Internal Fluid Mechanics for Aeropropulsion Systems
Center: LeRC

Innovative techniques are sought for analyzing flows in aeronautical propulsion systems for low subsonic through hypersonic speeds. Areas of interest include:

**Computational methods for internal flows:** Algorithms utilizing high-order upwind techniques, unstructured and solution-adaptive grid schemes. New methods for surface modeling and grid generation. Software strategies to simplify the parallel implementation of the above methodologies.

**Inlets and nozzles:** Advanced steady-state and time-dependent flow analyses and benchmark quality data for flow fields including shocks, boundary layers, boundary-layer control, separation, heat transfer, surface cooling, and jet mixing.

**Turbomachinery:** Advanced flow codes, physical models, and supporting validation data for both steady and unsteady flows including shocks, viscous effects, heat transfer, and tip-clearance effects in fans, compressors, and turbines. Novel concepts for instrumentation and flow visualization.

**Combustors and augmentors:** Highly efficient flow codes and novel measurement techniques for flows and physical processes, including fuel injection, spray evaporation and mixing, reaction mechanisms and kinetic rates for hydrocarbon oxidation and soot formation, and formation of solid and gaseous exhaust emissions.

**References:**


NASA Conference Publication 10063, Aeropropulsion '91, Sessions 9-12, Internal Fluid Mechanics Research, 1991. NASA-CP-10063

NASA Conference Publication 3078, Computational Fluid Dynamics Symposium on Aeropropulsion, 1990. N91-21062


### 01.02 Aeropropulsion System Components
Center: LeRC

A continuing demand exists for turbine engines with reduced fuel consumption for all classes of aerospace vehicles. Innovative concepts are needed for inlets, propellers and/or fans, compressors, combustors, turbines, nozzles, and recuperators and/or regenerators. Objectives include: greater component and cycle efficiency; lower gaseous and particulate emissions; reduced coolant penalties through advanced cooling concepts; and reduced weight, volume, and aerodynamic drag. Emphasis is on component aerodynamics and heat transfer; concepts which primarily address materials and structures are more appropriate in other subtopics. Improvements may be investigated using multi-disciplinary analysis methods, experimental methods, and/or advanced computational fluid dynamic methods.

**References:**


NASA Conference Publication 3049, Aeropropulsion '87, February 1990. N88-15790

NASA Conference Publication 10063, Aeropropulsion '91, March 1991. NASA-CP-10063


### 01.03 Aeropropulsion System Instrumentation, Sensors, and Controls
Center: LeRC

**Instrumentation and Sensors:** Propulsion system components are being exposed to increased thermal and aerodynamic loads. This requires that precise measurements of the severe operating environment and engine conditions be made for control, safety, and health monitoring considerations. To satisfy these requirements, innovative techniques and instrumentation are sought for accurate, minimally intrusive measurement of pressure, temperature, strain, flow, and other parameters. Measurement systems and sensor concepts of interest in the following areas:

- Strain and temperature measurements on both metal and ceramic surfaces up to 1650°C.
- Gas temperature and pressure measurements, both static and dynamic up to 1900°C.
- Silicon-carbide high-temperature electronics and integrated sensors.
- Fiber-optic and/or integrated-optic sensors and control systems.

- Aerodynamic flow and combustion diagnostic systems.
- Data processing techniques for non-intrusive, whole-field measurement systems.

**Controls:** New, powerful, onboard computing capabilities and new sensor technologies will enable achievement of optimum engine performance and life by incorporating artificial intelligence and feedback control. To achieve these objectives, innovations are sought in:

- Control of distributed systems, including distributed actuation concepts.
- Nonlinear or adaptive real-time controls.
- Redundancy management or fault detection.
- Improved component performance through compressor-stall alleviation, combustor-pattern factor control, or other advanced techniques such as integrated system intelligence and high-speed computation for artificial intelligence applications.

**References:**

NASA Conference Publication 100063, Aeropropulsion '91, Session 5, Instrumentation and Controls Research, March 20-21, 1991. N88-15794

Lorenzo, C.F., and Merrill, W.C., "An Intelligent Control System for Rocket Engines: Need, Vision and Issues," IEEE Control System Magazine, Vol. II, No. 1 (January 1991), 42-46. A91-26925

## 01.04 Propulsion Systems for General Aviation Aircraft

Center: LeRC

Proposals are invited for innovative concepts or integration of technologies in aircraft propulsion that are appropriate for use in general aviation aircraft. Objectives are to improve performance, safety and reliability, simplify operations, reduce maintenance and costs, and improve environmental compatibility (e.g., reduce community noise from aircraft operations). Areas of interest include the following:

- Simplified (single lever) power and/or airspeed controller systems,
- Automated engine performance monitoring systems,
- Innovative, alternative fuel engine concepts (e.g., rotary and diesel concepts),
- Improved propeller performance with reduced propeller noise,
- Reduced interior and exterior engine noise,
- Reduced cooling drag,
- Reduced vibrations, and
- Simplified inspection and maintenance.

Anticipated performance and/or cost benefits of introducing or integrating proposed innovative propulsion technologies into general aviation aircraft shall be quantitatively defined in the proposal using appropriate theoretical or experimental data. Proposals must be hardware-oriented for near-term problem solutions and applications; proposals for analyses or system studies are not acceptable.

**References:**

Propulsion Opportunities for Future Commuter Aircraft, William Strack. NASA TM-82915, 1982.

Huggins, George, and Ellis, David, Advanced General Aviation Comparative Engine/Airframe Integration Study. NASA CR-163364.

Wickenheiser, T.J., Knip, G., Plencner, R.M., and Strack, W.C., Comparison for Four Alternative Powerplant Types for Future General Aviation Aircraft, NASA TM-81584, October 1980.

Strack, William, New Opportunities for Future Small Civil Turbine Engines - Overviewing the GATE Studies, NASA TM-79073, Business and Aircraft Meeting, April 3-6, 1979.

## 01.05 Computational Structural Methods for Aeropropulsion

Center: LeRC

Computer simulation of the complex structural interactions that occur within the hostile, thermomechanical loading environment of aeropropulsion machinery is an extremely demanding computational problem. Many analyses, particularly complete propulsion system simulations, place extreme demands on computer resources or may require undesired simplifications of the analytical model. Advances in computer science and technology may alleviate some of these problems and allow costly experiments to be replaced with numerical simulation. These advances can also accelerate time-intensive simulations, achieve multi-variable optimization, and perform realistic probabilistic designs.

This subtopic solicits proposals for novel, innovative techniques for achieving any of the following objectives:

- Improved aeropropulsion structural and dynamic analyses and methods for design optimization including large interconnected multi-component systems.

- New machine architectures to solve problems in aeropropulsion system structures that often have cyclical symmetry and nonlinear response, are subjected to high temperatures, operate with high-speed rotations, and exhibit fluid-structure coupled response.

- Computer programs for parallel processors that handle machine-dependent aspects of their architectures. Algorithms that are developed under these environments should be equally applicable to other parallel machines with only minor changes to the code to obtain peak computing performance. Appropriate tools for interactive debugging and time profiling of code are needed for these portable environments as well.

**References:**

Lawrence, C., and Kiraly, L.J., Structural Dynamics Branch Research and Accomplishments for FY89, NASA Technical Memorandum 102488, July 1990. N90-26373

Standley, H.M., A Very High Level Language for Large-Grained Data Flow, 1987 Computer Science Conference (proceedings), St. Louis, MO, February 17-19, 1987. 90-70739

Janetzke, D.C. and Murthy, D.V., Efficient Computation of Aerodynamic Influence Coefficients for Aeroelastic Analysis on a Transputer Network, NASA Technical Memorandum 103671. AVAIL:CASI

# 02.00 Aerodynamics and Acoustics

## 02.01 Computational Fluid Dynamics

Center: ARC

More powerful numerical computation capabilities for predicting fundamental fluid flow phenomena can lead to improved aerodynamic and configurational optimization for aiding the aerospace industry with the design of future aircraft (subsonic and supersonic), missiles, and space vehicles. NASA's interest in computational fluid dynamics encompasses the entire spectrum of aerodynamic and aerothermodynamic phenomena that may be encountered by subsonic-to-hypersonic aircraft and aerospace vehicles. This research would advance understanding of static and dynamic behavior, transient phenomena, maneuvering, stability and control, aerodynamic performance, real-gas effects, heat transfer, and combustion phenomena. Applications include both external and internal flow fields and multiple body interactions.

This subtopic solicits proposals for novel approaches in any of the areas listed below.

**Numerical methods** for solving fluid-flow equations that increase computational efficiency, accuracy, speed, and utility. These include construction of new algorithms, improved computer languages, improved boundary condition procedures, efficient grid-algorithm interfacing, applications of automation techniques, and other innovative techniques.

**Analytical and numerical techniques** that enhance understanding of transition and turbulence phenomena and provide improved models for solving the Navier-Stokes equations.

**Grid-generation procedures**, unstructured grids, solution-adaptive procedures, and grid quality measures.

**Scientist's workbenches** with integrated, graphical tools for interactive geometry definition, grid-generation, flow visualization, and solution validation.

**Scientific visualization** including techniques to identify and visualize areas of complex flow physics.

**References:**

Sorenson, R., and McCann, K., "A Method for Interactive Specifications of Multiple-Block Topologies," AIAA paper 91-0147, Jan. 1991. A91-19157

Van Dam, C., et al., "Drag Calculation of Wings Using Several Euler Methods," AIAA paper 91-0338, Jan. 1991. A91-19240

Baldwin, B., and Barth, T., "A One-Equation Turbulence Transport Model for High Reynolds Number Wall-Bounded Flows," AIAA paper 91-0610, Jan. 1991. A91-19304

Narain, J., et al., "The Prediction of Viscous Hypersonic Flows About Complex Configurations Using an Upwind Parabolized Navier-Stokes Code," AIAA paper 91-0394, Jan. 1991. A91-21477

## 02.02 Flow-Physics Modeling and Flow Control
Center: LaRC

Performance improvements for all classes of aerospace vehicles are dependent, to a large measure, upon improved modeling of transition and turbulence in complex flows. Also required are practical flow control approaches for such phenomena as heat transfer, noise, shock wave drag, flow separation and vortices, as well as transition and turbulence, both free and bound. This subtopic solicits proposals for research on inventive and innovative flow-physics modeling and flow-control concepts applicable to:

- Transition and transitional flows across the speed range.
- Transition and turbulence-related phenomena such as heat transfer, skin friction, acoustics, and mixing rate.
- Complex flow phenomena such as flow separation, vortical flows including drag due to lift, and shock wave drag.

**References:**

Bushnell, D.M., and Hefner, J.N., "Viscous Drag Reduction in Boundary Layers," Progress in Astronautics and Aeronautics, Vol. 123, 1989. A91-12688

"Special Course on Skin Friction Drag Reduction" AGARD Report R-786, March 1992.

Bushnell, D.M., "Turbulence Modeling in Aerodynamic Shear Flow - Status and Problems," AIAA paper 91-0214, 1991.

Bushnell, D.M., "Longitudinal Vortex Control - Techniques and Applications," Aeronautical Journal, October 1992, pp.293-312.

## 02.03 Hypersonic Vehicle Aerothermodynamics
Center: ARC/LaRC

Innovative applications of computational and experimental aerothermodynamic technologies are sought which will account for the complex aerothermodynamic phenomena impacting the design and development of future planetary probes and hypersonic aerospace vehicles. Phenomena of interest include equilibrium and finite-rate chemistry; transport properties and multi-component mixing laws; thermal; radiation, gas-surface interactions such as surface catalytic reactions, shock-wave/boundary-layer interactions; and laminar, transitional, and turbulent viscous flows. Technology applications of interest include the extension of computational and experimental methodology to include the above phenomena, grid generation for complex hypersonic and reentry vehicles, diagnostics for high-enthalpy test facilities, and experiments to validate computational methods, assess nonequilibrium radiation effects about aerospace configurations, and measure physical properties such as phenomenological reaction rates.

**References:**

Park, Chul, Nonequilibrium Hypersonic Aerothermodynamics. John Wiley and Sons, 1990. A91-14483

Gnoffo, Peter A., Conservation Equations and Physical Models for Hypersonic Air Flows in Thermal and Chemical Nonequilibrium, NASA TP 2867, Feb. 1989. N89-16115

Allwright, S., Multiblock Topology Specification and Grid Generation for Complete Aircraft Configurations. AGARD CP 464, p. 11-1, 1989. N90-21986

Miller, C.G., Langley Hypersonic Aerodynamic /Aerothermo-Dynamic Testing Capabilities-Present and Future. AIAA Paper No. 90-1376, June 1990. A90-38483

## 02.04 High-Angle-of-Attack and High-Lift Configurational Aerodynamics
Center: ARC

The development of experimental and computational methods and data analysis procedures to enhance the basic understanding of low-speed aerodynamics and airframe-control-propulsion interaction phenomena would provide important contributions to high angle-of-attack and high-lift aerodynamic research. Combined improvements in aircraft performance, stability and control, and noise characteristics for future civil and military aircraft would be a significant benefit. The vortex-dominated flow fields require innovative techniques to define the interaction between vortices and boundary layers, shear layers, or solid surfaces. Extensive integration of modern sensor technology and/or sophisticated computer-experiment integration is considered an important element.

This subtopic solicits proposals for innovative concepts and techniques related to new and improved aerodynamic configurations for aircraft in the following areas:

- Vortex-flow control devices and wing configurations to improve body-wing-strake and slender wing performance.

- Integration of airframe, control surfaces, and propulsion systems to enhance the performance of all elements, including reducing noise.

- Interactive aerodynamic design, geometry definition, and graphical flow-field and solution visualization.

- Acoustic and pressure sensing methods.

**References:**

Ng, T., and Malcolm, G., "Aerodynamic Control Using Forebody Blowing and Suction," Eidetics International, Torrance, CA, AIAA-91-0619, Proceedings of AIAA 29th Aerospace Science Meeting, Reno, NV, January 7-10, 1991. A91-19387

Peraire, J., Peiro, J., Formaggia, L., et al., "Finite Element Euler Computations in Three Dimensions," International Journal for Numerical Methods in Engineering, Vol. 26 (1988), 2135-2159. A89-12130

Jameson, A., Baker, T.J., and Weatherill, N.P., "Improvements to the Aircraft Euler Method", AIAA Paper 87-0452, Jan. 1987. A87-22644

Nichols, M.R., "Bibliography on Aerodynamics of Airframe/Engine Integration of High Speed Turbine Powered Aircraft," NASA TM 8184, Nov. 1980. N81-11032

## 02.05 Unsteady Aerodynamics and Aircraft Dynamics

Center: LaRC

Maneuvering performance improvement in all classes of aircraft emphasizes the growing dominance of unsteady aerodynamics on aircraft dynamics. Successful design requires an understanding of complex, unsteady aerodynamic phenomena, particularly at conditions involving extensive flow separation. It also requires the development of experimental and analytical methods for reliably predicting these effects and their impact on aircraft flight dynamics, and the development of airframe design approaches for obtaining desired characteristics. Areas for innovation include:

- Aircraft configurational effects on unsteady aerodynamic characteristics.

- Methods for assessing the impact of unsteady effects on aircraft dynamics during early design.

- Flow-control concepts to exploit unsteady phenomena for performance and stability and control benefits.

- Approaches for mathematical modeling of unsteady aerodynamics for accurate simulation of aircraft maneuvering dynamics.

- Analysis of aircraft dynamic phenomena driven by unsteady effects such as wing rock, tumbling, post-stall gyrations, and empennage buffet, and development of methods for predicting such behavior.

**References:**

Nguyen, L.T., Flight Dynamics Research for Highly Agile Aircraft. SAE-892235

Brandon, J.M., and Shah, G.H., Unsteady Aerodynamic Characteristics of a Fighter Model Undergoing Large-Amplitude Pitching Motions at High Angles of Attack. AIAA-90-0309. A90-26933

## 02.06 Rotorcraft Aerodynamics and Dynamics

Center: ARC

Many aspects of rotorcraft aerodynamics and dynamics are not thoroughly understood or adequately modeled in proprietary or commercial analysis tools. Areas of importance include: aerodynamics of rotor-airframe-tail interactions; rotor-blade air-flow loading analyses; improved rotor system performance; analysis of advanced hub designs and their influence on rotor dynamics; rotorcraft vibration and vibration alleviation; aeroelastic stability; rotor noise; and new rotor concepts for high-speed flight.

This subtopic solicits proposals for the development of novel concepts and innovative methods to produce greater understanding of the basic phenomena involved in these areas and greater knowledge of their detailed characteristics. Advances are needed for making verifiable, accurate predictions for current rotorcraft configurations--including tilt-rotors, single main rotor and tandem helicopters, and co-axial helicopters-- and for defining next-generation, high-speed rotorcraft--specifically, rotorcraft vehicles with relatively low disk loading and the efficient, low-speed attributes of a helicopter but with a high-speed cruise capability of 300-450 knots.

**References:**

Martin, D.M., Mort, R.W., Young, L.A., et al., "Hub- and Pylon-Fairing Integration for Helicopter Drag Reduction," Proceedings of the 46th American Helicopter Society Annual National Forum, Phoenix, AZ, May 1991. N77-27436

Hefferman, R.M., Yamauchi, G.K., Gaubert, M., et al., "Hub Loads Analysis of the SA349/2 Helicopter," Journal of the American Helicopter Society, Vol. 35, No. 1 (January 1990). A90-23936

Stremel, P.M., "Calculation of Flow about Two-Dimensional Bodies by Means of the Velocity-Vorticity Formulation on a Staggered Grid," 29th Aerospace Sciences Meeting, Reno, NV, January 7-10, 1991. A91-21551

Talbot, P.D., "High Speed Rotorcraft: Comparison of Leading Concepts and Technology Needs," Proceedings of the 46th American Helicopter Society Annual National Forum, Phoenix, AZ, May 1991. AVAIL:AIAA

## 02.07 Aeroacoustic Research in Wind Tunnels
Center: ARC

Simulations of flight effects on aircraft noise generation and propagation are made in closed-jet and open-jet wind tunnels. Advances are needed in test techniques to ensure proper fidelity and scaling of the noise sources generated aerodynamically. Special instrumentation, algorithms, and test techniques are needed to capture radiated noise from wind tunnel models and avoid pseudo-noise from the flow-field and wind-tunnel drive system. The necessity for quiet, anechoic test conditions are important to data quality. Finally, both aerodynamic and acoustic test techniques and predictions are needed to properly exploit the research areas best served by wind-tunnel testing such as propulsion/airframe interactions, forward-speed effects on propulsion noise, airframe noise, and flight effects on jet noise suppressors. Proposals for innovative concepts and techniques are solicited in the following areas:

- Quiet microphones and support struts for inflow noise measurements.
- Acoustic antennas and signal processing for improved signal-to-noise ratio.
- Control of turbulence-induced sound on models and microphones.
- Simulation and scaling of aeroacoustic noise sources.
- Sound propagation inflow and through shear layers--prediction and corrections to flight.
- Wind tunnel background noise suppression.
- Simulation and prediction of airframe noise and propulsion/airframe aeroacoustic interaction.
- Integrated design and performance of noise-suppressor mixer ejectors and high-lift wings.

**References:**

Soderman, Paul T., and Allen, Christopher S., "On the Scaling of Small-Scale Jet Noise to Large Scale," NASA TM 103921. (Also - DGLR/AIAA paper 92-02109, DGLR/AIAA 14th Aeroacoustics Conf., Aachen, Germany, May 1992). A93-19195

Soderman, P.T., and Horne, W.C., Acoustic and Aerodynamic Study of A Pusher-Propeller Aircraft Model. NASA TP 3040, Sept 1990. N91-21828

Olson, L.E., Zell, P.T., Soderman, P.T., Falarski, M.D., Corsiglia, V.R., and Edenborough, H.K., "Aerodynamic Flow Quality and Acoustic Characteristics of the 40-by 80-Foot Test Section Circuit of the National Full-Scale Aerodynamic Complex," SAE Tech Paper 872328, Dec. 1987. (SAE 1987 Transactions Aerospace, Sect. 6, Vol. 96, pp. 6.1557-6.1572). A88-37197

Soderman, P.T., and Hoglund, L.E., "Wind-Tunnel Fan Noise Reduction Including Effects of Turning Vanes on Noise Propagation," AIAA Paper 79-0642, March 1979. A78-22524

## 02.08 Wind Tunnel Instrumentation
Center: LaRC

Innovative concepts and techniques are needed for the following areas of wind tunnel instrumentation:

- Noninterfering or nonintrusive transition monitors for flow-field visualization in boundary layers in conventional and cryogenic wind tunnels.
- Quantitative spectroscopic flow field diagnostics.
- Multidimensional, global measurement of surface and flowfield properties.
- Measurement of combustion efficiency in scramjet pulse facilities by $H_2O$ products of $O_2/H_2$ combustion.
- Ultrahigh sensitivity optical sensor and amplifier system capable of resolving laser-induced fluorescence lines for molecular state characterization.
- Hot wire/hot film calibration techniques for supersonic and hypersonic flows.
- Miniaturized heat flux sensors for high heating rates (up to $5 \times 10^6$J/m$^2$-sec).
- Miniaturized pressure sensors for 1-350 kPa range for high temperature environments (up to 1700 K) and frequencies up to 100 kHz.
- Static and dynamic calibration of pressure sensors for temperatures up to 1700 K and frequencies up to 100 kHz.
- Pressure-sensitive paint and/or coating systems for applications in conventional and cryogenic wind tunnels.
- Infrared optical fibers for image relay to the IR imagers in the range 2-5 $\mu$m and 8-12 $\mu$m.
- Nonintrusive measurements of temperature and pressure in thin skin models.
- A fast system for model attitude measurement with an accuracy of 0.005°.
- Skin friction sensor for temperatures in the range of -160° to +540° C.
- Smart optoelectronic materials for laser safety glasses for a wide range of frequencies (from ultraviolet to infrared).

**References:**

Proceedings of "1992 NASA Langley Measurement Technology Conference," edited by J. J. Singh and R. R. Antcliff. NASA CP-3161, 1992.

"Aerodynamic Measurement Technology: Focus '92." Aerospace America, Vol. 30 (No. 11), pages 16-39, 1992.

McKenzie, Robert L., "Progress in Laser Spectroscopic Techniques for Aerodynamic Measurements--An Overview." AIAA Paper #91-0059, January 1991.

## 02.09 Aircraft Noise Prediction and Reduction

Center: LaRC

Technology for better control of noise and associated acoustic loads is needed for developing acceptable aircraft and rotorcraft. Advancement of this technology requires understanding fundamental noise source mechanisms, propagation paths, and response of receivers. Sources of noise and acoustic loads include: jet exhaust plumes, rotors, propellers, boundary layers, turbulent flow, and aerodynamic surface interactions. Propagation paths include inhomogeneous atmosphere and aircraft structures. Receivers can be either people or aircraft structures. In addition to the fundamental understanding of the source, path, and receiver, improved prediction methods and control and reduction concepts are needed.

- Fundamental and applied CFD techniques for aero-acoustic analysis.
- Reduction concepts and prediction methods for noise radiation and associated acoustic loads of supersonic jet plumes and for high-frequency, fluctuating pressure loads on airframes of supersonic and hypersonic aircraft.
- Prediction of high-frequency dynamic response and sonic fatigue characteristics of advanced light-weight structures to acoustic loads at elevated temperatures.
- Concepts for active or passive interior noise control for aerospace vehicles.
- Reduction concepts and prediction methods for rotorcraft and advanced propeller aerodynamic noise.
- Methods for predicting and assessing the sonic-boom impact of supersonic transports.

**References:**

Brooks, et al., "Reduction of Blade/Vortex Interaction Noise Through Higher Harmonic Pitch Control," J. Am. Hel. Soc., Vol. 35, No. 1 1990, pp. 86-91. A90-23937

Farassat, et al., "Advanced Turboprop Noise Prediction Based on Recent Theoretical Results," J. Sound Vib., Vol. 119, No. 1 1987, pp. 53-79. A88-24303

Seiner, et al., "Dynamic Pressure Loads Associated with Twin Supersonic Plume Resonance," AIAA J., Vol. 26, No. 8 1988, pp. 954-960. A89-16111

## 02.10 Propulsion Noise Reduction

Center: LeRC

A wide range of future aircraft types must employ low-noise, highly efficient propulsion systems at subsonic, transonic, or supersonic flight speeds. This subtopic solicits proposals for innovative noise reduction concepts, noise prediction methodology, and instrumentation for diagnostic noise measurements. Noise reduction concepts should be supported by analysis and experimental verification. Specific areas of interest include:

- Practical and efficient jet and fan source noise reduction concepts for both subsonic and supersonic civil transports.
- Active noise control concepts, such as source alteration and advanced acoustic treatment enhancement.
- Diagnostic techniques and instrumentation to determine acoustic source locations and characteristics, modal content, and propagation paths.
- Prediction of the steady and unsteady aerodynamics and acoustics, including acoustic treatment, of fans and ducted propellers (ultra-high bypass ratio fans) at both design and off-design conditions.
- Prediction of the noise from subsonic and supersonic and supersonic jets and the noise generated by internal mixing of flows at different velocities and temperatures.

**References:**

Groeneweg, J.F., Sofrin, T.G., Rice, E.J., and Gliebe, P.R., "Turbomachinery Noise," Aeroacoustics of Flight Vehicles: Theory and Practices, Vol. 1: Noise Sources, pp 151-209, NASA Reference Publication 1258, August 1991. N92-10601

Groeneweg, J.F., and Rice, E.J., "Aircraft Turbofan Noise," Journal of Turbomachinery, Vol. 109 (Jan. 1987), 130-141. A87-31144

Seiner, J.M., and Krejsa, E.A., "Supersonic Jet Noise and the High Speed Civil Transport," AIAA-89-2358, July, 1989. A89-46772

## 02.11 High Performance Aerodynamic Improvements

Center: ARC

Proposals are solicited for innovative detailed configuration modifications to improve the aerodynamic performance of high-performance subsonic and supersonic aircraft. If within the scope and funding limits of SBIR projects, Phase II may include specific wind tunnel or flight test experiments to verify performance gains, or development of innovative computational techniques for predicting specifically proposed improvements that could be verified experimentally and incorporated into multidisciplinary design tools. Examples of areas of particular interest for aerodynamic performance improvement include:



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- Induced drag reduction.
- Supersonic cruise performance.
- Maximum lift for finite wings.
- Three-dimensional boundary layer control.

**References:**

Waters, M., Ardema, M., Roberts, C., Kroo, I., "Structural and Aerodynamic Considerations for An Oblique All-Wing Aircraft," AIAA Paper No. 92-4220, Aug. 1992. A93-13336

Reuther, J., Cliff, S.E., Hicks, R.M., "Practical Design Optimization of Wing/Body Configurations Using the Euler Equations," AIAA Paper No. 92-2633, June 1992. A92-45505

Smith S.C., Kroo, I.M., "A Closer Look at the Induced Drag of Crescent-Shaped Wings," AIAA Paper No. 90-3063, Aug. 1992. A90-50638

Gallman, J.W., Kroo, I.M., Smith, S.C., "Design Synthesis and Optimization of Joined-Wing Transports," AIAA Paper No. 90-3197, Sept. 1990. A90-49102

## 02.12 General Aviation Aircraft Configurations

Center: ARC/LaRC/LeRC

Proposals are invited for innovative concepts for integrating aircraft configuration technologies in ways appropriate to general aviation systems. Objectives include the improvement of performance, safety, utility, and compatibility in the nation's airspace system, together with reduction of manufacturing and operating costs and environmental impact. Suggested areas of interest and specific technologies for possible integration may include the following:

- Practical drag reduction techniques.
- Natural laminar flow and hybrid laminar flow control.
- Turbulent drag reduction devices (e.g. riblets).
- Improved airfoil and aerodynamic controls designs and methods.
- Sheared wing tips.
- Advanced and unconventional configurations (e.g. free-wing).
- Simplified high lift systems.
- Stall/spin resistance.
- Improved ride and control quality in gusts and/or turbulence.
- Practical gust load alleviation.
- Active noise control.
- Practical computational methods for aerodynamic or configuration design and analysis (e.g. fluid dynamics, aerodynamics, source noise and noise propagation prediction).
- Applications of ice-protection systems to composite and metal aircraft.

Anticipated performance and/or cost benefits of proposed concepts and systems shall be quantitatively defined in the proposal. Proposed innovations must emphasize practical, near-term hardware applications; proposals for general studies and systems analyses are not acceptable. Proposed project scope must be compatible with SBIR program performance periods and funding limits.

**References:**

Viscous Drag Reduction in Boundary Layers: Edited by Dennis M. Bushnell and Jerry N. Heffner. Vol. 123, Progress in Astronautics and Aeronautics; A. Richard Seebass, Editor-in-Chief. Published by the American Institute of Aeronautics and Astronautics, Inc., 1990.

Natural Laminar Flow and Laminar Flow Control. R.W. Barnwell, and M.W. Hussaini, Editors. Published by Springer-Verlag, New York Inc., 1992.

Roskam, Jan, Airplane Design. Roskam Aviation and Engineering Corp., Ottawa, KA., 1989.

## 03.00 Aircraft Systems, Subsystems, and Operations

### 03.01 Aircraft Ice Protection Systems

Center: LeRC

Improved aircraft icing protection remains an important aviation safety objective. This subtopic solicits innovative concepts that will lead to highly effective and efficient ice protection systems and techniques for helicopters, general aviation aircraft, commercial transports, and military aircraft.

The areas of greatest interest are the sensing, removal, and prevention of inflight and ground ice on aircraft surfaces; in particular, non-intrusive, flight-worthy sensing systems, in-flight ice protection systems that minimize weight and power consumption, and ground protection techniques that maximize protection time and minimize aerodynamic and environmental impact.


**References:**

Reinmann, J.J., "NASA's Aircraft Icing Technology Program," NASA TM 104518 December 1991. N91-20120

Zumwalt, G.W., et al., "Electro-Impulse De-Icing Testing Analysis and Design," NASA CR 4175, September 1988. N90-10031

Soeder, R.H., and Andracchio, C.R., "NASA Lewis Icing Research Tunnel User Manual," NASA TM 102319, Ju[illegible] N90-2[illegible]407


### 03.02 Aircraft Weather Environment

Center: LaRC

This subtopic requests innovations that minimize aircraft flight hazards due to weather. By improving predictability, detection, and avoidance of weather hazards and by providing a data base for design criteria. Hazards considered here are heavy rain, winds, wind shear, turbulence, lightning, and wake turbulence. Innovative improvements are needed in airborne equipment suitable for measuring environmental effects and in algorithms for alerting the pilot and crew of impending changes in weather and flight hazard conditions.

**Lightning effects:** Assessment of the effects of lightning on future advanced composite aircraft employing flight critical digital systems; data for the prediction of lightning-aircraft interactions and direct strike data; techniques for predicting lightning-induced effects on systems in advanced composite aircraft.

**Airborne sensors:** For the detection of low-altitude wind shears.

**Airport weather monitoring:** Determination of timing for the relaxation of wake vortex separation constraints; determination of the influence of weather on the persistence and decay of wake turbulence; assessment of the hazard presented by weather-reduced strength vortices.

**Airborne weather monitoring and processing system:** Acceptance of data from various sensor units (airborne and ground-based) to provide hazardous weather information to the pilot.


**References:**

NASA CP 10050, Airborne Wind Shear Detection and Warning Systems, July 1990. N91-11682, N91-11695

Greene, G.C. "An Approximate Model of Vortex Decay in the Atmosphere," AIAA Journal of Aircraft, Vol. 23, No. 7 (July 1986), 566-573. A86-44889

AGARD CP 470, Flight in Adverse Environmental Conditions, September 1989. N90-15401


### 03.03 Control Concepts for Fixed Wing Aircraft

Center: LaRC

Modern vehicle design concepts rely heavily on advanced controls techniques to enhance mission performance and efficiency and to expand flight envelope. Both aircraft and transatmospheric vehicle flight profiles must be carefully tailored and controlled over a broad range of mission objectives to avoid limits imposed by aerodynamic heating, structural, and propulsion considerations. There is a growing trend in the dynamic coupling between disciplines that require the use of numerous control effortors, including thrust-vectoring concepts, to achieve desired stability margins and performance levels. Current and future mission requirements dictate that conventional control system design criteria must be re-examined and redefined. Improved synthesis methods must be developed for highly integrated, multidisciplinary, dynamic systems. Among the key challenges will be the need to provide proper interfaces between the airframe and propulsion system, the guidance and control systems, the pilot, and the exterior situation.

This subtopic solicits proposals for innovative advances to the technologies involved, with emphasis on any of the areas listed below.

- Guidance laws and concepts including trajectory optimization.
- Readily implementable, full-envelope, control-law design algorithms.
- Pilot-vehicle interface techniques.

- Utilization of knowledge-based, expert systems, or neural networks concepts.
- Control system design and aircraft performance metrics.
- Reliable onboard aircraft state estimation.
- System identification and parameter extraction.

**References:**

McRuer, D., Ashkenas, I., and Graham, G., "Aircraft Dynamics and Automatic Control," Princeton University Press, Princeton, New Jersey, 1973. A74-31219

Raymer, P., "Aircraft Design: A Conceptual Approach," American Institute of Aeronautics and Astronautics, Washington, DC, 1989.

Blakelock, J.H., "Automatic Control of Aircraft and Missiles," John Wiley & Sons, Inc., New York, 1991.

Stevens, B.L., and Lewis, F.L., "Aircraft Control and Simulation," John Wiley & Sons, Inc., New York, 1992.

## 03.04 Sensing Technologies for Aircraft Low-Altitude Operations

Center: ARC

Nap-of-the earth (NOE) flight in a conventional helicopter is currently extremely taxing for two pilots under visual flight rule (VFR) conditions. Developing a single-pilot all-weather NOE capability will require significant automation. A major goal would be the development of pilot-centered, computer-sensor aiding concepts for enhanced NOE flight-control capability. Many of the sensing technologies for enhancing NOE flight-control capability are also useful in enhancing crew situational awareness for commercial aircraft and emergency helicopters under reduced visibility conditions. Innovative approaches are sought to advance technologies in the following areas:

- Integration of three-dimensional information from diverse sources such as range estimates from passive and active sensors and stored database of terrain and man-made objects.

- Post-processing of such information for display to pilots or for use by automated flight control systems.

- Enhanced situational awareness during approach, landing, and taxiing.

- Model-based and real-time machine vision.

**References:**

Sridhar, B., Soursa, R., Smith, P., and Hussien, B., "Vision-Based Obstacle Detection for Rotorcraft Flight," Journal of Robotic Systems, Vol.9, No.6, September 1992, pp. 709-727. A92-52465

Cheng, V.H.L., and Sridhar, B., "Technologies for Automating Rotorcraft Nap-of-the-Earth Flight," Proceedings of the AHS 48th Annual Forum, Washington, D.C., June 3-5, 1992, pp. 1539-1554.

## 03.05 Flight Research Sensors and Instrumentation

Center: ARC

Real-time measurement techniques are needed to acquire aerodynamic, structural, and propulsion system performance characteristics in flight and to expand safely the flight envelope of aerospace vehicles. This subtopic solicits proposals for improved airborne sensors and instrument systems in subsonic, supersonic, and hypersonic flight regimes. These sensors and systems are required to have fast response, low power, low volume, minimal intrusion, and high accuracy and reliability. Innovative concepts are solicited in the following areas:

- Temperature, pressure, density, flow angle, and velocity measurements.

- Turbulence measurements up to Mach 0.8.

- Air data parameters (airspeed, air temperature, ambient and stagnation pressures, Mach number, and air density)

- Boundary-layer flows using visualization.

- Surface acoustics employing optical technology.

- Off-surface flow fields, including vortical and separated flow, suitable for CFD code validation for regions from the surface to 50 feet away.

- Strain on advanced structures at 1700°C and above.

- Aerodynamic skin friction on flat and curved surfaces and in the presence of streamwise pressure gradients.

- Structural deflections from Mach 3 to Mach 10 using optical methods.

- Thin-film, pressure-measurement technology to provide static and dynamic measurements for low-speed, transonic, or high-speed applications.

**References:**

Instrument Society of America, Proceedings of the 35th International Instrumentation Symposium. Orlando, FL, May 1-4, 1989. A89-19651

Instrument Society of America, Proceedings of the 34th International Instrumentation Symposium. Albuquerque, NM, May 2-6, 1988. A89-27651

Instrument Society of America, Proceedings of the 33rd International Instrumentation Symposium. Las Vegas, NY, May 3-8, 1987. A88-33051

## 03.06 Aircraft Flight Testing Techniques

Center: ARC

Advanced hardware and/or software tools are needed to reduce the cost of aircraft ground and flight testing, to obtain more complete or more meaningful information, and also to increase confidence in the measured information. Innovations are sought for the following:

- On-line estimation of the vibratory characteristics of flight vehicles.
- On-line monitoring of engine or aerodynamic performance parameters.
- Applications of smart sensors or sensor and actuator arrays for monitoring and control of the airframe or aerodynamics.
- Advanced algorithms to identify impending instabilities in the airframe or propulsion subsystems (e.g. aeroelastic flutter, engine stall, spin/departure).
- High-resolution flow visualization tools to locate vortex flows and laminar-to-turbulent flow transition in a wide variety of flight conditions.
- Identification of various instability modes affecting boundary-layer transition and separation.
- Laser systems for measuring aircraft inlet-flow characteristics, shock position and strength, and engine-exhaust flow conditions for the purposes of inlet and/or engine control and thrust calculation.
- In-flight signal processing tools and/or techniques for any of the above applications.

**References:**

McCormick, B.W., "Aerodynamics, Aeronautics and Flight Mechanics," Wiley, 1979. A79-52571

Nelson, Robert, "Flight Stability and Automatic Control," McGraw, 1989. ISBN 0070462186

Inman, Daniel J., "Vibration: With Control, Measurement, and Stability," Prentice-Hall, 1989. ISBN 0-13-942709-8

## 03.07 Hypersonic Vehicle Design and Systems Technology

Center: LaRC

Emerging concepts for airbreathing propulsion systems, combined cycle engines, airframe-engine integration, light-weight structures and tankages, cryogenic insulation and high-temperature thermal protection systems, and subsystems may produce the necessary dryweight fraction in conjunction with the propulsion and aerodynamic performance needed for hypersonic airbreathing vehicles. Innovations that enable the use of advanced hypersonic technologies for vehicle design, development, and optimization are sought in the following areas:

- Three-dimensional numerical design methods for external and internal vehicle and propulsion flow-path analyses.
- Methods applicable to optimizing the total configuration.
- Vehicle sizing and scaling algorithms.
- Computer-aided design software applicable to the design of hypersonic aircraft at the conceptual and preliminary levels.
- Heat exchangers, reactor, and secondary coolant designs for endothermic fuel systems in hypersonic aircraft.
- Advanced propulsion cycles applicable from Mach 0-to-5 or 25 and accompanying design and integration techniques.
- Advanced heat-rejection radiators, compact, high-performance convective heat exchangers and cooling panels designs.
- Durable coatings or insulation systems that can significantly reduce the aerothermal heat load to external and/or internal surfaces.

**References:**

Pegg, R.J., Petley, D.H., Spitzer, C.R., Jones, S.C., Martin, J.G., and Moses, P.L., Conceptual Design of a Mach 5 Carrier-Based Aircraft. NASA TM 102634, March 1990.
Limited to U.S. Gov't Agencies & Contractors X90-10345

McClinton, C.R., CFD Support of NASP Design. AIAA 90-3252. Presented at the AIAA/AHA/ASEE Aircraft Design, Systems, and Operations Conference, Dayton, Ohio, September 17-19, 1990. A90-49120, A91-14472

Pinckney, S.Z., and Walton, J.T., Program SRGULL: An Advanced Engineering Model for the Prediction of Airframe-Integrated Subsonic/Supersonic Hydrogen Combustion Ramjet Cycle Performance. NASP TM 1120, August 1990. AVAIL:CASI

Pegg, R.J., et al., Design of a Hypersonic Waverider-Derived Airplane. Presented at the 31st Aerospace Sciences Meeting & Exhibit, Reno, Nevada, January 11-14, 1993.

## 03.08 Very-High-Altitude Aircraft Technology
Center: ARC

NASA currently has no subsonic flight capability above 70,000 feet but is interested in developing a high subsonic speed, atmospheric sampling aircraft, either manned or unmanned, and capable of at least three hours endurance at altitude with a 1,000 lb. payload. The physical properties of the atmosphere change quickly with altitude beyond 80,000 feet, and atmospheric flight at such extreme altitudes poses significant challenges. This subtopic solicits innovative proposals that advance aerospace technologies toward the development of subsonic aircraft for sustained flight above 100,000 feet altitude.

Specific areas of interest for this subtopic include: aerodynamics; propulsion; structures and materials; guidance, control, and navigation; aeroelastic and aeroservoelastic flight dynamics; and other technologies related to flight at extreme altitudes. The results sought are marketable solutions to specific problems or marketable design tools. Proposals for studies involving the development of specific design configurations are not of interest unless they are to determine the feasibility of innovative concepts that have not been previously reported in the open literature.

**References:**
NASA CP 10041, "Global Stratospheric Change: Requirements for a Very-High Altitude Aircraft for Atmospheric Research Workshop," Truckee, CA, July 15-16, 1989. N90-14220

Chambers, Alan, and Reed, R. Dale., "A Very-High Altitude Aircraft for Global Climate Research," The Magazine of the Association for Unmanned Vehicle Systems, Vol. 8, No. 3 (1990), 14-19. AVAIL:ESL

## 03.09 Aeronautical Human Factors and Flight Management
Center: ARC

Rapid developments in aerospace and computer technology have made it feasible to automate many crew functions thereby intensifying, not eliminating, the need for careful attention to human performance. Humans do not cease to make errors when interacting with automated systems; they simply tend to make different errors. An important objective in aerospace human-factors research is to address the interaction of humans with engineered systems. As the crew's role evolves from that of system operator to that of system manager, innovative technological devices, techniques, tools, and models are needed in the following areas that pertain to the automation environment, crew information processing and decision making, and associated cognitive workload:

**Operational concepts and crew-system interfaces** involving cockpit displays of flight management information to ensure the efficient and safe use of ATC system technology.

**Electronic control and display** for consolidating and integrating the man-machine interface, including electronic display media, pictorial multimode display generation, and multifunction controls.

**Status monitoring systems** that inform, advise, or aid the flight crew; other advanced input and output devices and methods for voice synthesis and recognition, pointing, and touch.

**Flight path planning, replanning, and communication aids** to facilitate safe and efficient flight operations.

**Human response measurement** for assessment of crew workload and situation awareness.

**References:**
Boff, K.R., and Lincoln, J.E., "Engineering Data Compendium: Human Perception and Performance," Harry G. Armstrong Aerospace Medical Research Facility, Vols I-III (1988). N88-28630, N88-28631, N88-28632

Degani, A., and Weiner, E.L., "Human Factors of Flight-Deck Checklists: The Normal Checklist," NASA Contractor Report 177549, May, 1990. AVAIL:CASI

Elkind, J.I., Card, S.K., Hochberg, J., et al., "Human Performance Models for Computer-Aided Engineering," New York: Academic Press, 1990. ISBN 0122365305

Weiner, E.L., and Nagel, D.C., "Human Factors in Aviation," New York, Academic Press, 1988. A89-34431

## 03.10 Testing and Verification of Flight-Critical Systems
Center: ARC

Accurate and reliable methods for reducing the time required to validate critical systems are needed for the design and modification of modern aircraft systems, particularly to enhance a systems engineers' ability to understand system interactions, determine the effect that a component has on the overall system and perform system validation.

This subtopic solicits proposals for innovative projects that will provide the following:

- The capability to perform systems sensitivity analysis when using variable performance system or subsystem components. Products that can simulate system nominal and off-nominal performance could be integrated such that decisions on the system's ability to complete the desired functions would be influenced.
- A higher degree of automation in the areas of test definition and analysis of test results. The focus would be on products with the ability to use the same documentation that is used to build the system as opposed to describing the system with a separate test language.
- Accurate, on-line documentation for complex, highly integrated systems that allows documentation to be organized by each systems engineer to best suit the particular application.

**References:**

Sitz, Joel R., "F-18 Systems Research Aircraft Facility," NASA TM 4433 1992. N93-16753/AVAIL:CASI

Sitz, Joel R., and Vernon, Todd H., "Flight Control System Design Factors for Applying Automated Testing Techniques," NASA TM 4240, 1990. A91-54610

Chacon, Vince, Pahle, Joseph W., Regenie, Victoria A., "Validation of the F-18 High Alpha Research Vehicle Flight Control and Avionics Systems Modifications," NASA TM 101723N90-28542

Mackall, Dale, and Allen, James G., "A Knowledge-Based System Design/Information Tools for Aircraft Flight Control Systems," NASA TM 101704, 1989. A90-10491, N90-13990

## 03.11 Aerospace Vehicle Flight-Characteristics Simulation

Center: ARC

Safer and more efficient design of advanced aerospace vehicles such as the High Speed Civil Transport requires advancements in current predictive design tools. The goal of this subtopic is to develop more effective software tools for predicting and understanding the response of an airframe under the simultaneous influence of aerodynamics, the control system, and the propulsion system, in addition to pilot commands. The benefits of this effort will ultimately be increased flight safety (particularly during flight test), more efficient aerospace vehicles, and an increased understanding of the complex interactions between the aforementioned subsystems.

This subtopic solicits proposals for novel, multi-disciplinary, linear or nonlinear, dynamic systems simulation techniques. Successful projects are expected to yield marketable computer code that address one or more of the objectives listed below.

- Prediction of steady and unsteady pressure and thermal load distributions on the aerospacecraft surfaces, or similar distributions due to propulsive forces, by employing accurate CFD techniques.
- Effective numerical algorithms for multi-disciplinary systems-response analysis with adaptive three-dimensional grid or mesh generation at selected time steps.
- Effective use of high-performance computing machines, including parallel processors for integrated system analysis or pilot-in-the-loop simulations.
- Innovative applications of high-performance computer graphics or virtual reality systems for visualizing the computer model or results.
- Correlation of predictive analyses with test data or model update schemes based on measured information.

**References:**

Gupta, K.K., Brenner, M.J., and Voelker, L.S., "Integrated Aeroservoelastic Analysis Capability with X-29A Comparisons," AIAA Journal of Aircraft, Vol. 26, No. 1 (January 1989), 84-90. A89-24311

Gupta, K.K., Petersen, K.L., and Lawson, C.L., "Multidisciplinary Modelling and Simulation of a Generic Hypersonic Vehicle," AIAA Third International Aerospace Planes Conference, 3-5 December 1991, Orlando, FL, paper No. AIAA-91-5015. A92-17813

## 03.12 General Aviation Flight Systems and Operations

Center: ARC/LaRC

Proposals are invited for innovative concepts and integration of technologies for flight systems that are appropriate to general aviation. Objectives are to increase or improve situational awareness and aircraft mission performance in all weather flight conditions, increase systems reliability, ease pilot workloads and improve safety during congested airspace operations. Areas of interest include:

- Intuitive controls (e.g., decoupled controls, single-lever airspeed control).

- Intuitive displays (e.g., moving maps, graphical cockpit weather information systems).
- GPS (and/or LORAN) -based traffic conflict systems.
- GPS (and/or LORAN) -based enroute and terminal guidance, navigation, and control systems (including non-precision and precision approaches).
- Three-dimensional terrain database terminal navigation aids.
- Digital and/or optical storage and retrieval of aircraft performance and weight and balance data.
- Optical computer memory systems (CD ROM).
- Satellite-based communications systems.
- Fiber-optic-based communications and control systems.

Proposals should address the integration of all navigation, weather, traffic, and aircraft performance information required for aircraft operations in visual and instrument meteorological conditions (VMC & IMC). Displays should be intuitively or instinctively recognizable, rapidly learned, and readily retained so that reduced initial and recurrent training requirements may be achieved. Any integrated system should provide the pilot with near real-time indications of current and planned flight route conditions and provide suitable alternatives when the flight plans become hazardous.

Offerors must also address the value of their proposed innovations on utility, safety, performance, cost, manufacturability, certifiability, maintainability, and environmental impact, as appropriate, and should also identify National Airspace System (Air Traffic Control) requirements necessary for these advanced technology aircraft to operate safely and effectively. Proposals must be directed to specific hardware-oriented objectives in near-term applications. System studies are not acceptable.

**References:**
Bergeron, Hugh P., and Shaughnessy, John D., Controls, Displays, and Information Transfer for General Aviation IFR Operations. NASA CP 2279, Oct. 1983.

Bergeron, Hugh P., and Hinton, David A., Aircraft Automation: The Problem of Pilot Interface. Published in Journal "Aviation, Space, and Environmental Medicine" in 1984.

"Aeroacoustics of Flight Vehicles: Theory and Practice", Volume 1: Noise Sources, Volume II: Noise Control: NASA Reference Publication 1258, Volumes I and II, WRDC Technical Report 90-3052, August 1991.

## 03.13 General Aviation Systems Integration and Test

Center: ARC/LaRC

Proposals are invited for modifications to existing general aviation aircraft for use in flight tests of innovative concepts integrating one or more advanced technologies for general aviation aircraft that are solicited under other subtopics in this Solicitation (e.g. configuration design, structures and materials, propulsion systems and cockpit systems). The objective is to facilitate realistic and practical concept evaluations and verifications in order to reduce industry development risks and to expedite early commercial applications.

Offerors may propose suitable modifications to their own aircraft or propose joint ventures for this purpose. Joint ventures and the firms forming them must qualify as small businesses. Offerors may propose the use of specific NASA aircraft, but because there is no current assurance that NASA can make such aircraft available, offerors submitting such proposals risk being declined on that basis. All proposed projects must be consistent with the scope, performance intervals, and cost limits of NASA SBIR projects.

**References:**
Chambers, J.R., and Stough, H.P., III, Summary of NASA Stall/Spin Research for General Aviation Configurations. AIAA Paper No. 86-2596, Sept. 1986.

Stough, H.P., III, and Holmes, B.J., NASA Small Civil Airplane Research. SAE Paper No. 87404, Nov. 1987.

Yip, L.P., Robelin, D.B., and Meyer, H.F., Radio-Controlled Model Flight Tests of a Spin Resistant Trainer Configuration. AIAA Paper No. 88-2146.

Stewart, E.C., A Simulation of a Display and Control System Requiring Reduced Training and Proficiency. AIAA/FAA Joint Symposium on General Aviation Systems, Wichita, KS, Mar. 16-17, 1992.

## 04.00 Materials and Structures

### 04.01 Adaptive Deployable Structures for Small Spacecraft
Center: JPL

Future NASA missions will employ smaller, more affordable spacecraft whenever possible. Smaller size will require special attention to deployable appendages including antennas, solar arrays and science booms. Requirements will include low weight and storage volume as well as reliable deployment, rigidity, alignment accuracy and controllability after deployment. Such requirements are not new for spacecraft, but smaller size may introduce unusual design difficulties and also offer new design opportunities.

Innovative concepts for the design of deployable appendages for future small spacecraft are solicited. Concepts may include but are not limited to inflatable structures and rigidization techniques using active elements such as piezoelectric or shape memory alloys to enhance and maintain static and dynamic structural properties, and to prevent loss of structural integrity after deployment which might result from space debris damage or other factors.

**References:**

Freeland, R.E., and Bilyeu, G., "In-STEP Inflatable Antenna Concept," Paper No. IAF 92-030, Proceedings of the 43rd Congress of the International Astronautical Federation, Washington, D. C., August 28-September 5, 1992. A92-55729


### 04.02 High-Performance Polymers for Aircraft Applications
Center: LaRC

Improved polymers for films, coatings, and adhesives for structural and other functional uses are required for long-term (60,000 to 120,000 hours), high-temperature (>150°C) applications in aircraft and in the hostile environments of space. Applications include metal-to-metal, metal-to-composite and composite-to-composite bonding, and bonding various films and substrates. Improved polymers must achieve desired characteristics with suitable toughness, easy processability, environmental durability, and low cost.

Proposals are solicited for synthesis and development of innovative, improved chemistry polymers or new formulations of state-of-the-art polymers to meet the stated requirements.

**References:**

Lee, S.M., ed., International Encyclopedia of Composites. New York, VCH Publishers, NY, 1990. ISBN 0895732904


### 04.03 General Aviation Aircraft Structures and Materials
Center: LaRC

Proposals are invited for innovative improvements in the field of structures and materials that are appropriate for advanced technology general aviation aircraft. Areas for improvement include manufacturing methods and cost reduction, resistance to environmental hazards, safety, certifiability, maintainability, durability, utility, and operating costs. Example areas of interest include:

- Low cost composite manufacturing techniques.
- Automation in manufacturing of metal or composite aircraft.
- Improved crashworthiness design methods and devices for composite airframes.
- Reduced vulnerability to the effect of lightning and HIRF.
- Computational structural mechanics design methods specifically for general aviation applications.

Proposals must be for innovative concepts or integration of technology to achieve specific, near-term, hardware-oriented problem solutions by the offeror; general and system studies are not acceptable.

**References:**

Boltnott, R.L., and Fasanella, E.L., Impact Evaluation of Composite Floor Sections. Presented at SAE General Aviation Aircraft Meeting and Exposition, April 11-13, 1989, Wichita, KS.

Dexter, H.B., Harris, C.E., and Johnston, N.J., Recent Progress in NASA Langley Textile Reinforced Composites Program. Presented at the Second NASA Advanced Composites Technology Conference, November 4-7, 1991. NASA CP-3154, pp. 295-323, June 1992.

Beyer, T.B., and Silcox, R.J., Noise Transmission Characteristics of a Large Scale Composite Fuselage Model. AIAA 13th Aeroacoustics Conference, October 22-24, 1990, Tallahassee, FL. AIAA-90-3965

Deaton, Jerry W., Kullerd, Susan M., and Portanova, Mark A., Mechanical Characterization of 2-D, 2-D Stitched, and 3-D Braided/RTM Materials, Presented at Third NASA Advanced Composites Technology Conference held in Long Beach, California, June 8-11, 1992. NASA CP-31-78, Part 1, pp. 209-230, January 1993.

## 04.04 Composite Materials for Aircraft and Space Applications
Center: LaRC

**Aircraft Structures:** High-performance composites are being developed with high structural efficiency and reduced costs for airframe structural applications on subsonic and supersonic aircraft. Innovations are sought in the following specific areas: textile preforms, low-cost fabrication technology, automated process control for composite fabrication, low-cost tooling for such fabrication methods as resin transfer modeling, low-cost fabrication of prepreg and towpreg, rapid methods to fabricate consolidated carbon-fiber-reinforced thermoplastic ribbon, and thermoforming. Lightweight core materials for high-temperature sandwich construction, polymer-based matrices, and reinforcement fibers from organic and inorganic precursors are also desired.

**Spacecraft Materials:** Ultra-high-performance composites will be utilized in future spacecraft. Innovations are needed in the following areas: lightweight core materials for precision sandwich space structures such as reflectors and optical benches, ultrahigh performance composites, fabrication technology for high precision structural sub-elements, and concepts for "smart materials" to provide on-orbit control of space structures.

**References:**

Lubin, George, Handbook of Composites. New York, Van Nostrand Reinhold Company, NY, 1982. A82-42651

Lee, S.M., ed., International Encyclopedia of Composites. New York, VCH Publishers, NY, 1990. ISBN 0895732904

## 04.05 Adaptive, Intelligent, or Smart Aerospace Structural Components
Center: LaRC

The integration of adaptive, intelligent, or smart materials into structural components for future aerospace missions applications should help reduce cost, size, weight, and power while increasing performance. Among such materials are electrostrictive materials, piezoelectric ceramics and polymers, magnetostrictive materials, and shape-memory alloys and polymers. Structural concepts of interest are those which will produce predictable changes in geometry and/or mechanical properties in response to a disturbance. Improvements are needed in integrating the geometrical and/or mechanical function into a structural concept. Consideration should be given to toughness, load capability, motion and frequency bandwidth, and simplicity of operation for the intended applications.

**Spacecraft applications** include, for example, concepts for instrument pointing, tracking and/or isolation, launch load alleviation, antenna shaping and/or reshaping, and vibration suppression of jitter from solar arrays. Operating environments include vacuum, large temperature changes, cosmic radiation, low available power, and dynamic disturbances from attitude control systems, solar arrays, and/or multiple tracking payloads.

**Aircraft applications** include concepts for the twisting of a wing for aircraft control thus eliminating conventional flaps, motion control of winglets and wing leading and trailing edges, control of wing surface for flutter suppression, engine vibration reduction, and acoustic noise reduction for improved passenger comfort. Aircraft operating environments are atmospheric with wide dynamic pressure and climatic variations.

**References:**

Proceedings of the AIAA/ASME/ASCE/AHS/ASC 32nd Structures, Structural Dynamics, and Materials Conference, Baltimore, MD, April 8-10, 1991, Part 1;- Materials, Engineering Optimization, Works In Progress, 15 Papers on Adaptive Structures, pp 2179-2297.

## 04.06 Electrically Conductive and Nonlinear Optical Polymeric Materials
Center: LeRC

Recent advances in polymer science have led to materials with high electrical conductivity and nonlinear optical (NLO) behavior. Conductivities now approach that of copper while the electrochromic behavior of many of these polymers presents unique opportunities and new applications for these materials. Polymeric nonlinear optical materials have faster switching times and better responses than inorganic systems, e.g., $LiNbO_3$. Use of electrically conductive polymers and polymeric nonlinear optical materials in space power and communications could result in enhanced performance, reduced manufacturing cost, and reduced system weight. Advances in new chemistry and processing could lead to significant improvements in the processing, performance, and environmental stability of these materials.

This subtopic solicits proposals for innovative concepts in the synthesis and processing of new conductive polymers and polymeric NLO materials that can lead to improvements in their processability, environmental stability, and performance.

**References:**

Kanatzidis, M.G., "Conductive Polymers" Chem. and Eng. NASA HQ News, Vol. 68, No. 49 (1990), 36-54. ISSN 0009-23347

Chiang, L.Y., Chaikin, P.M., D.O., eds., "Advanced Organic Solid State Materials," Mat. Res. Soc. Symp. Proc., 1990, 173. ISBN 1558990615

Prasad, P.N., Ulrich, D.R., eds., Nonlinear Optical and Electroactive Polymers. New York, Plenum Press, 1988. ISBN 0306427680

Meador, M.A.B., Gaier, J.R., Good, B.S. et al., "A Review of Properties and Potential Aerospace Applications of Electrically Conductive Polymers," SAMPE Quarterly, Vol. 21, No. 5 (1990), 23-31. A91-14409

## 04.07 High Temperature Superconductors
Center: LaRC

Innovations are desired in high-temperature superconductive materials for both thick film and bulk applications.

**Thick Film Electronics:** Proposals are solicited for thick film superconductive devices printed onto low thermal conductivity substrates. Innovations in multilayer fabrication, superconductor/substrate interfacial control, and grain alignment are desired.

**Magnetic Levitation:** Innovations are sought in materials capable of producing a high levitative force for application as magnetic bearings, positioning devices, and vibration dampers and in forming techniques for production of bulk superconductive ceramics into coils, cables, and cavities. Techniques for property enhancement should be combined, if possible, with forming techniques incorporating flux pinning sites and inducing preferred orientation.

**High Field Magnets:** Materials for use in constructing high-field-strength magnets and the design of such magnets suitable for use in large gap suspension and control in wind tunnel magnetic balance suspension systems are needed.

**References:**
Romanofsky, R.R., and Sokoloski, M.M., Prospects and Progress of High Tc Superconductivity for Space Applications, NASA-CP-3100, April 1990.

## 04.08 Containment of High-Temperature Gases
Center: LaRC

High-temperature refractory materials are required for forming high-temperature (i.e. > 3,000 K at 10 MPa) gas reservoirs. To obtain such a gas reservoir temperature, a container material is heated to a temperature in excess of 3,000 K by use of an optical energy source. Hence, the container material must provide mechanical, thermal, and optical properties suitable for heating, and for sustaining the high temperature. The container materials must be rigid and solid and have a high melting point, moderate fabricability, high thermal conductivity, and high spectral absorptivity for optical heating. The materials must be able to not only withstand oxidation, but also maintain their mechanical strength in response to frequent heating loads. New approaches developing and applying refractory materials are invited. These advanced materials will be very useful for providing gas reservoirs for flow sources, high temperature ion chambers, and for a variety of plasma containment devices.

**References:**
Lackey, W.J., et al., "Ceramic Coatings for Heat Engine Materials - Status and Future Needs," ORNL-Technical Memorandum-8959, Dec. 1984. N85-29053

Shoji, J.M., et al., "Windowed Porous Material Absorption Concept - A New Solar Thermal Propulsion Concept", 1986 JANNAF Propulsion Meeting, Vol. 1, p. 119-126. N87-26098

## 04.09 Materials to Withstand Space Environmental Effects
Center: MSFC

Spacecraft materials of the future must be stable when exposed to the combined environmental effects of space for extended periods of time, in some instances exceeding 30 years. The combined environment that can significantly degrade materials includes vacuum, thermal cycling, solar ultraviolet radiation, high energy protons and electrons, micrometeoroids, and, in low earth orbit, neutral atomic oxygen and orbital debris. Innovative materials, material modifications, material testing, and instrumentation must be developed to meet this challenge.

- Atomic oxygen protective coatings for spacecraft materials that are stable in the combined space environment, are non-flammable and non-toxic, and have low off-gassing characteristics.

- Thermal control coatings with selectable thermal radiative properties that are stable when exposed to the synergistic effect of the natural space environment including spacecraft induced contamination.

- Instrumentation for characterization and verification of materials thermal radiative properties and their stability.

- Materials and instrumentation for micrometeoroid and/or space debris protection, impact detection, and damage evaluation.

**References:**
Teichman, L.A., and Stein, B.A., eds., "Space Environmental Effects on Materials Workshop," NASA Conf., Hampton, VA, Pub. 3035, 1988. N89-2328

Levine, A.S. ed., "LDEF-69 Months in Space First, First Post-Retrieval Symposium", Conference Publication NASA CP-3134, June 1991. N92-23280-Part 1, N92-24806-Part 2 N92-27083-Part 3

## 04.10 Special Purpose Materials for Space Applications

Center: GSFC

Improved and new materials are desired for many spacecraft applications, including those listed below. All materials must be low outgassing and in all ways compatible with spacecraft applications.

- Thread-locking compounds with a range of shear strengths.
- Urethanes, silicones, and epoxies cured by use of UV light and resistant to chemical attack and abrasion.
- O-ring and gasket materials having low shrinkage when cooled to -100°C for use in high vacuum and pressurized systems.
- Epoxy adhesives for bonding metals and composites for use above 250°C.
- Laminated printed circuit-board materials with tailored coefficient of thermal expansion to alleviate thermal fatigue of soldered joints.
- Thermally conductive, flat black paint for thermal control for use in the range +100°C to -196°C.

**References:**
Griffin, Michael D., and French, James R., "Space Vehicle Design," AIAA Series, Washington, DC. AVAIL:AIAA

"Fracture Control Safety Policy and Requirements for Payloads Using the Space Transportation System," published by NASA, NHB 1700.7B. AVAIL:CASI

## 04.11 Lubricants for Aeronautics and Space Applications

Center: HQ/LeRC/MSFC

Advanced aeronautics and space missions and service requirements place stringent demands on lubrication for surfaces and mechanical components. Innovative, new concepts for both liquid and solid lubricants for dependable, long-life service under strenuous operational environments are sought in the following areas with emphasis on development, testing, and processing:

**Long-life, dry-film lubricants and self-lubricating composites** for applications requiring long-term survival in space environments without degradation of lubricating properties. Of special interest are mechanism lubricants for use in long-duration low Earth orbit lasting up to thirty years. These lubricants should emphasize resistance to degradation under exposure to atomic oxygen, which is known to cause rapid degradation of most organic materials and dry film lubricants having organic binders.

**Liquid lubricants for long-term space applications** that exhibit low creep, low volatility, and stability under all exposures.

**Wide-temperature solid-lubricant materials** capable of operating to 800°C to 1000°C for advanced aeronautics and space applications.

**Liquid lubricants for advanced, gas turbine engine applications** having bulk oxidation stabilities from 330°C to 400°C.

**References:**
Zaretsky, E.V., "Liquid Lubrication in Space," Tribology Int., Vol. 23, No. 2 (April 1990), 75-93. N90-28063

Roberts, E.W., "Thin Solid Lubricant Films in Space," Tribology/Int., Vol. 23, No. 2 (April 1990), 95-104. ISSN 0301-679X

Jones, Jr., W.R., et al., "The Preparation of New Perfluoroether Fluids Exhibiting Excellent Thermal-Oxidative Stabilities," I&EC Research, Vol. 27 (1988),1497-1502. N86-25475

Visentine, J.T. and Whitaker, A.F., NASA TM-100351, Material Selection Guidelines to Limit Atomic Oxygen Effects on Spacecraft Surfaces. X89-10321

## 04.12 Magnetic Bearing Technology

Center: LeRC

Magnetic bearings, by eliminating physical contact between rotors and stationary parts, avoid bearing life problems and lubrication systems. Furthermore, they offer substantial advantages in vibration control, including adjustable bearing stiffness and damping, shifting of rotor critical speeds, a variety of methods to counteract rotor imbalance. They also permit higher rotor speeds and larger diameter shafts because of the removal of surface speed limitations associated with rolling element bearings. Magnetic bearings show potential for a broad range of applications, including gas turbine engines and spacecraft propulsion systems.

Innovations in magnetic bearings are solicited in the following areas:

- Improved designs to minimize the size and weight of the bearing and supporting electronics and to reduce power consumption.

- Improved analysis capabilities for simulation and design of electro-mechanical systems associated with magnetic bearing and rotordynamic systems.

- Concepts and materials to enable high-temperature applications such as gas turbine engines and to enable cryogenic applications.

- Sensors, health monitoring, and fault tolerant designs.

**References:**


O'Connor, Leo, "Active Magnetic Bearings Give Systems A Lift," Mechanical Engineering, July, 1992, Vol. 114, No. 7. A92-48201

Fleming, David P., "Magnetic Bearings - State of the Art" NASA TM-104465, July 1991. N91-25418

"Structural Dynamics Branch Research and Accomplishments for FY90" NASA TM 103747, November 1991. N92-15406


## 04.13 Space Mechanical Components

Center: LeRC

Mechanical devices and moving parts in general are vital to current and future space missions. Failures or degradation of such basic mechanical components as bearings, gears, and seals can compromise mechanism performance or interrupt spacecraft operation. Problems often stem from limitations inherent in the components themselves as well as from system performance requirements and the rigors imposed by space.

Innovations in mechanical component concepts, designs, and technology are sought to solve various mechanism shortcomings. Advanced mechanical components to be considered include bearings (but not magnetic bearings), seals, actuators, drives, and related devices. Requirements include long life, reliability, and one or more of the following:

- Expanded operating envelope of rotating space machinery.

- Reduced torque ripple and increased bandwidth of high-precision (e.g., pointing) mechanisms.

- Inherently clean (no outgassing, absorption, or particle generation) for use in non-contaminating mechanisms.

- Inherent redundancy or imbedded self-diagnostics.

- Devices for providing long-term, in-service lubrication (but not the lubricants themselves) or relubrication of mechanical components.

- Basic mechanical components that can be integrated into equipment or vehicles designed for lunar and martian surface operation. Required characteristics include robustness, low or zero maintenance, efficiency, and tolerance to the environment.

**References:**


Loewenthal, S.L., and Schuller, F.T., "Feasibility Study of a Discrete Bearing/Roller Drive Rotary Joint for the Space Station," NASA TM-88800, July 1986. N80-30206

Steinetz, B.M., Rohn, D.A., and Anderson, W.J., "Evaluation of a High Torque Backlash-Free Roller Actuator;" 20th Aerospace Mechanisms Symposium, NASA CP-2423 (revised), 1986, pp.205-230. N87-16336

Fusaro, R.L., "Space Mechanisms Technology Needs--A Government/Industry Response"; NASA TM (in process), 1991.

"Structural Dynamics Branch Research and Accomplishments for FY 1989"; NASA TM-102488, NASA Lewis Research Center, July 1990. N90-26373


## 04.14 Welding and Related Metals Processes Technology

Center: MSFC

Innovative means for controlling welds and improving properties of weldments are needed to achieve lower cost, lighter weight, and more reliable aerospace components and assemblies. Areas in which innovations are desired include:

- Physically-based mathematical models of metal cutting, casting, and forming, and weld phenomena such as high-speed machining, net shape forming, weld penetration, shielding, and defect formation. The relation of final product parameters for any of the above processes to process parameters (e.g. weld strength to weld structure) for use in the development of process control systems.

- Methods for modifying materials to improve formability or weldability without degrading other desired material properties. Materials of interest include: high-strength steels, nickel-based alloys, aluminum-lithium alloys, metal-matrix composites.

- Simulations of metals processes, utilizing graphic displays, correlated to actual process parameters and databases.

- Vacuum welding processes that modify and improve the weldability of normally difficult-to-weld materials.

**References:**
Brosilow, R., "Space Shuttle Files on Computer Welds," Welding Design and Fabrication, Description of Welding System Architecture for NASA Welds, (August 1989). AVAIL:ESL

Nunes, Jr., A.C., Bayless, Jr., E.O., Jones, III, C.S., et al., "Variable Polarity Plasma Arc Welding on the Space Shuttle External Tank," Welding Journal, Description of the VPPA Welding System developed at NASA-MSFC, Vol. 63, No. 9 (June 1984), 27-35. A84-48541

Lancaster, J.F., ed., The Physics of Welding, 2nd Ed., International Institute of Welding. Review of the Current Understanding of the Physical Basis of the Welding Process, Pergamon Press, 1986. A8028749

"Major Repair of Structures in an Orbital Environment". Report No. SA-ROS-4 Grumman Aerospace Corporation, NASA-MSFC Contract No. NAS8-36436, June 1987. Review of background considerations for space welding. N90-70123

### 04.15 Laser Welding of Ceramics
Center: MSFC

Many current NASA programs require the use of ceramic materials to survive extremely high temperatures. Ceramic materials have excellent resistance to heating, wear, and corrosion. However, it is difficult and expensive to fabricate complex parts that can be used in NASA's programs. Laser welding of simple ceramic components can provide a more cost-effective solution to fabricating complex systems of ceramic materials.

This subtopic requests innovations in techniques for laser welding of ceramic materials. Typical programs should provide hardware and processes for producing welds on ceramics of interest including pure ceramic materials as well as hybrid (ceramic and refractory metal) materials for use in elevated temperature environments.

**References:**
Arata, Y., "C02 Laser Welding of Ceramics", Plasma, Electron and Laser Beam Technology, ASM, p. 506 ff, 1986. A87-35059

MacDowell, J.E., and Beall, G.H., "Immiscibility and Crystallization in A1203-SiO2 Glasses", Journal of the American Ceramic Society, vol. 52, No. 1. (1969), 17-25. ISSN 0002-7820

### 04.16 Non-Destructive Monitoring of Composite Structures
Center: HQ

The innovation desired is a capability for real-time health monitoring of composite structures. It should be capable of indicating discontinuities and impact damage initiation and growth, as well as providing information about the degradation of material properties. Sensors can be either embedded or attached to the monitored structure. The system should perform either continuous or periodic interrogation and reporting on structural integrity. This system is intended to reduce the amount of non-destructive evaluation needed for periodically deployed structures or to report on the structural integrity of deep space vehicles and optical systems. The system should interface to a computer through standard forms of communication.

**References:**
Lesko, J.J., Carman, G.P., Miller II, W.V., Vengsarker, A.M., Reifsnider, K.L., Claus, R.O., "Embedded Fabry-Perot Fiber Optic Strain Sensors in the Macromodel Composites," Optical Engineering, Vol. 31, No. 1, January 1992. ISSN 0091-3286

Takat, K., "Fiber Sensors Take Wing in Smart-Skin Applications," "Smart-skin fiber sensors offer real-time monitoring of the structural health of tomorrow's aircraft," Photonics Spectra, p. 88, April 1991. ISSN 0731-1230

Claus, R.O., "Fiber Sensors As Nerves for 'Smart Materials'," Photonics Spectra, p. 75, April 1991. ISSN 0731-1230

"Proceedings of 1992 Military Communications Conference - MilCom '92." ISBN 070830585X

### 04.17 Non-Destructive Evaluation of Material Properties
Center: LaRC

Innovations are solicited for characterizing material properties using non-destructive evaluation (NDE) techniques. Traditionally, NDE has been a final check-out procedure for quality assurance. Quantitative NDE should be applied at developmental phases of new materials as well as process phases of engineering materials. The desired benefits are improved safety, reliability, and economic advancement for various aerospace systems; reduced development time for introducing new materials and structures; reduced costs in developing and maintaining aerospace systems; and means to make informed decisions for safe and economic life extension of aging systems.

Proposals should involve novel technology and instrumentation to address the state of health of both space and aircraft systems in practical situations, including aging airfleet evaluation, and must focus on development of non-destructive probing energies to determine aerospace material properties related to their performance requirements. NDE opportunities include the development of measurement science instrumentation for characterizing new, high-temperature materials and aluminum-lithium alloys; detecting and measuring surface contamination as it relates to adhesive bonding; effects of atmospheric and space environment on materials; effects of stress, fatigue, and corrosion; microstructural imaging and characterization; electronic materials NDE; and in situ lifetime monitoring of current and future materials and structures.

**References:**

Madaras, E.I., Winfree, W.P., Smith, B.T., Heyman, J.S., "Detection of Bondline Delaminations in Multilayer Structures with Lossy Components," Proceedings of IEEE Ultrasonics Symposium, 1987. N88-21256

Heyman, J.S., "NDE Research for Aging Aircraft Integrity," Proceedings of IEEE Ultrasonics Symposium, Honolulu, HI, December 4-7, 1991. AVAIL:AIAA

Cantrell, J.H., and Qian, M., "Signal Generation in Scanning Electron Acoustic Microscopy," Material Science Engineering, Volume A122, Page 47, 1989.

## 04.18 Processing of High-Temperature Composites

Center: LeRC

A deterrent to the widespread use of high-temperature composites in aeropropulsion and commercial applications is low and/or variable properties due to flawed microstructures. This is particularly true for intermetallic and ceramic composites. The nature of the flawed microstructures varies widely; e.g., pores, cracks, undesirable phases, inhomogeneities in grain-size, phase and/or fiber distribution, damaged and reacted fibers, uncontrolled fiber-matrix interface quality, and contaminated surfaces. Methods must be developed to improve consolidation processing control to eliminate or minimize these flawed microstructural features.

This subtopic solicits proposals for new, imaginative, and innovative approaches to composite consolidation and/or subsequent processing techniques to produce metallic, intermetallic and ceramic matrix composites with improved properties, quality, and homogeneity.

**References:**

Ceramic Engineering and Science Proceedings, Parts 1 and 2, American Ceramic Society, July-August, 1991 ISSN 0196-6219

Buckley, J.D., ed., 14th Conference on Metal Matrix, Carbon and Ceramic Matrix Composites, Parts 1 and 2, Cocoa Beach, FL, Jan. 17-19, 1990. Part 1: X91-10103, NASA-CP-3097-PT-1
Part 2: X91-10125, NASA-CP-3097-PT-2
Limited by ITAR

## 04.19 Adaptive Control Techniques for Fabricating and Testing Metallic Materials

Center: LaRC

Real-time measurements and feedback and control techniques are required to optimize fabrication practice and maximize testing information for high-temperature metallic materials, including metal-matrix composites for airframe structural applications. The development of new critical materials could be enhanced and accelerated with the application of reliable sensors, instrumentation, and control systems integrated into fabrication and testing procedures. Innovative approaches to process control and testing instrumentation are sought in the following areas:

**Metal powder and metal-matrix composite consolidation:** temperature, pressure, force on work part, platen motion, change in volume or shape or work part.

**Thermal spray metal deposition:** spray parameters, deposited material temperature, thickness, substrate temperature.

**High temperature materials testing:** test specimen temperature, nonintrusive techniques for measuring strains, strain rates, deflections, etc., of materials under load at temperatures up to 1000° C, furnace energy input parameters, environmental parameters such as pressure, humidity, chemistry.

**Small supersonic arc-tunnel testing:** gas flow rates, composition, pressure, enthalpy, arc power and current, stagnation test specimen temperature, specimen dimension changes.

**References:**

Bird, R.K., and Brewer, W.D., "Fabrication and Characterization of SCS-6/Ti-1100 Composites", 15th Conference on Metal Matrix, Carbon, and Ceramic Matrix Composites, Cocoa Beach, FL, January 1991. X92-10156 Limited by ITAR

Singleton, O.R., and Royster, D.M., "Laboratory Produced P/M Aluminum 2XXX + Zr Sheet," Journal of Metals, vol. 40, Nov. 1988., p. 40-43. A89-20976, ISSN 0148-6608

Kennedy, J.R. et al., "Effect of Thermal Exposure, Forming, and Welding on High-Temperature, Dispersion-Strengthened Aluminum Alloy: Al-8Fe-1V-2Si. Final report, May 1989-June 1991. NASA-CR-187575, N91-32200

## 04.20 Sprayed Metal and Ceramic Coatings

Center: MSFC

Innovative means of in-process sensing and observation during spraying of metal and ceramic coatings and structures are needed to more closely monitor the process, thus providing better control of the spraying operation. New processes are needed, since many coatings are considered to be environmentally "unfriendly". Specific areas of interests are:

- New coating processes.

- Improvements in filtering techniques of spent powder.
- Accurate part temperature before, during, and after spraying.
- Means of observing the powder pattern as it enters the plasma.
- Means of measuring thickness of the spray deposit as well as its texture (roughness, waves).
- Fabrication of near net shape parts or assemblies.

**References:**

McKechnie, T.N., and Holmes, R.R., "Vacuum Application of Thermal Barrier Plasma Coatings", Advanced Earth-to-Orbit Propulsion Technology 1988, Vol. 1, pp. 692-702. N90-28653

McKechnie, T.N., and Wooten, J.R., "Vacuum Plasma Sprayed NARloy Z", Advanced Earth-to-Orbit Propulsion Technology 1990, Vol. 1, pp. 251-261. X91-10304 Limited by ITAR

Houck, David L., Editor, Thermal Spray: Advances in Coating Technology, Proceedings of the National Thermal Spray Conference, 14-17 September 1987. A88-53551

Berndt, C.C., Editor, Thermal Spray: International Advances in Coatings Technology, Proceedings of the International Thermal Spray Conference, May 28-June 5, 1992.

## 04.21 Coatings on Fibers for Ceramic and Intermetallic Composites

Center: LeRC

Coatings on continuous fiber reinforcements are needed to assure optimum structural and environmental performance of advanced intermetallic and ceramic matrix composites. These composite systems offer high technical payoff in terms of weight savings and performance for propulsion and power systems for aerospace and terrestrial applications. Since life and durability of these composite materials are strongly controlled by the nature and stability of the fiber-matrix interaction, this subtopic is soliciting proposals for innovative approaches in the processing, evaluation, and testing of fiber coatings.

**Coatings** that reduce or eliminate problems associated with interfacial reaction, CTE-mismatch between fiber and matrix, and fiber environmental degradation, particularly those that offer better performance than the current graphite and boron nitride coatings.

**Processing:** innovative cost-effective production approaches are required for multifunctional and structurally graded coatings that address these property needs.

**Evaluation and testing** characterization of the thermophysical and thermostructural properties of fiber coatings, especially with regard to internal stresses that can develop during coating and composite processing and during composite service.

**References:**

Everrett, R.K., Skowrorek, C.J., Pattnaik, A., Hahn, T., and Krause, D., "Diffusion Barriers and Compliant Layers for Fibers in Titanium Aluminide Matrices", 13th Conference on Metal Matrix, Carbon, and Ceramic Matrix Composites, Cocoa Beach, FL, January 18-21, 1989, p.557-567. X90-10253 Limited by ITAR

Misra, A.K., "Theoretical Analysis of Compatibility of Several Reinforcement Materials with NiAl and FeAl Matrices", 13th Conference on Metal Matrix, Carbon, and Ceramic Matrix Composites, Cocoa Beach, FL, January 18-21, 1989, p.207-225. X90-10231 Limited by ITAR

Larkin, D.J., Interrante, L.V. and Bose, A., "Application of Chemical Vapor Deposited Yttria for the Protection of Silicon Carbide Fibers in a SiC/$Ni_3Al$ Composites", Journal of Materials Research, Vol. 5, No. 11, 1990, p.2706-2717. ISSN 0884-2914

## 04.22 Electrically Conducting Diamond Coatings

Center: HQ

Advances in materials processing have made it possible to produce diamond films or coatings on a variety of substrates, including metals and ceramics. These coatings are characterized by high hardness and tensile strength, high electrical resistivity, high thermal conductivity, and high resistance against chemical abrasion and against sputtering by a variety of plasma species. It is anticipated that the electrical characteristics of such diamond films or coatings can be altered substantially by doping with selected impurities such as boron, thorium, or chromium to produce fully conducting, as well as semiconducting materials.

In this solicitation we seek innovative approaches to use doping techniques to produce highly conducting, wear-resistant diamond coatings that have the potential of extending the life-times of critical components of such electric space thrusters as hollow cathodes and extraction grids in ion thrusters, and of electrode surfaces in arcjet thrusters. However, many other applications of highly conducting diamond coatings may be envisioned, both in the commercial and space sectors.

Proposed techniques to produce the coatings may include alternative uses of the very types of space thrusters whose properties the new coatings seek to improve. Specific examples include the use of arcjet-like thrusters to produce the diamond coatings, and the use of ion sources for ion implantation of the desired impurities.

**References:**
Rebello, J.H.D., Straub, D.H., and Subramaniam, V.V., "Diamond Growth from a $CO/CH_4$ Mixture by Laser Excitation of CO: Laser Excited Chemical Vapor Deposition," J. Appl. Phy., Vol. 72, No. 3, p. 1133 (1992). A92-50419

Loh, M.H. and Cappelli, M.A., "Supersonic DC-Arcjet Plasma at Subtorr Pressures as a Medium for Diamond Film Synthesis," AIAA paper 92-3534, 28th Joint Propulsion Meeting, Nashville, TN, July 6-8, 1992. A92-49054

Hocking, M.G., Vasantasree, V., and Sidky, P.S., "Metallic and Ceramic Coatings: Production, High Temperature Properties, and Applications," Longman Scientific & Technical, Exxex, 1989. A90-45608

## 04.23 Modeling of Thermal Barrier Coating Response to a Thermal Cycle Environment

Center: LeRC

Thermal barrier coatings (TBC) have been used to increase the life of combustors in aircraft gas turbine engines for over thirty years and on first and second stage vanes in the turbine section for more than seven years. However, the greatest potential advantage offered by a TBC is gained when it is used on turbine blades to allow significant increases in turbine operating temperature. Under the operating conditions of this rotating component, if the TBC spalls, life is severely degraded. To achieve a reliable protective coating, it is necessary to both understand the failure mechanism of TBCs and to take steps to improve the coating durability through property modification. While simple testing has led to the identification of operative failure mechanisms, a complete understanding of TBC failure is not in hand. For example, two prominent mechanisms, oxidation and thermal expansion mismatch, can interact synergistically, greatly complicating the interpretation of the TBC failure.

This subtopic solicits development of models of TBC failure and innovative concepts to increase TBC life. Models must address realistic-time and temperature-dependent mechanical and physical properties of the constituents, the imposed thermal conditions, and the interfacial geometry of the substrate-TBC system.

**References:**
Brindley, W.J., and Miller, R.A., Adv. Matls. and Proc., TBCs for Better Engine Efficiency, Vol. 136, No. 2, 1989, p. 29-33. A90-17294

Chang, G.C., Phucharoen, W., and Miller, R.A., Behavior of Thermal Barrier Coatings for Advanced Gas Turbine Blades, Surf. Coat. Tech. Vol. 30, 1987, p. 13-28. ISSN 0257-8972

Miller, R.A., NASA TM 100283, Life Modeling of Thermal Barrier Coatings for Aircraft Gas Turbine Engines. N88-15060

## 04.24 Thermal Protection Materials and Systems

Center: ARC

Future atmospheric entry vehicles such as aerobraking orbital transfer, manned and unmanned planetary entry (lunar and Mars vehicles), and transatmospheric vehicles will require reusable thermal protection materials and ablative and/or reflective thermal protection materials systems that are more durable and lower in weight than those currently available. This subtopic solicits innovative concepts for new high- and low-density, rigid and flexible, ceramic materials and systems having extremely good thermal-shock resistance and temperature capability in the range from 1000°C to 2500°C.

Among the possible materials are $Si_3N_4$, SiC, BN, $Al_2O_3$, and other refractory carbides, nitrides, and borides. Possible forms are fiber-fiber composites, fiber-matrix composites, foams, and various woven forms developed into thermal protection system components for flexible thermal barriers, gap fillers, and high temperature structural composites for application to future entry vehicles.

Ablative materials using non-catalytic and radiation-reflecting technologies are required for planetary entry and return missions. For environmental durability, innovations are required to provide long life, water proofing, and increased toughness. This applies to both materials and techniques for future composite thermal protection materials as well as the state-of-the-art shuttle orbiter. New minimum-weight, load-bearing, and non-structural thermal protection systems using new components and processing methods are of interest.

**References:**
Chiu, S.A., and Pitts, W.C., "Reusable Surface Insulations for Reentry Spacecraft," Paper AIAA-91-0696, 29th Aerospace Sciences Meeting, Reno, NV, January, 1991. A91-21589

Stewart, D.A., and Leiser, D.B., "Thermal Stability of Ceramic Coated Thermal Protection Materials in a Simulated High-Speed Earth Entry," Ceram. Engr. & Sci. Proc., No. 8 (1988), 1199-1206. A89-19479, ISSN 0196-6219

Leiser, D.B., Churchward, R., Katvala, V., "Advanced Porous Coating for Low Density Ceramic Insulation Materials," J. Am. Ceram. Soc., Vol. 72, No. 6 (1989), 1003-1010. AVAIL:ESL

Rasky, D.J., Bull, J.D., and Tran, H.K., "Ablation Response of Advanced Refractory Composites," Proceedings of the 15th Annual Conference on Composites, Materials and Structures, Restricted Session, Advanced Ceramics Association, Cocoa Beach, FL, January, 1991. AVAIL:ESL

## 04.25 Bonding Techniques for High-Temperature Components

Center: GSFC

Devices constructed using a mixture of steel, aluminum, ceramic, and graphite components are envisioned that are mechanically strong, vacuum tight, and able to withstand both high-temperature and chemically reactive environments without leaks or fractures. Permanent, low-resistance metal-graphite joints able to withstand high temperatures and high current loads would greatly simplify the construction and durability of compact, high-temperature graphite furnaces. Similarly, graphite-steel or ceramic-steel welded reaction tubes would provide the high-temperature stability of graphite or ceramic components with the ease of construction of off-the-shelf stainless steel vacuum hardware. Such an arrangement would eliminate vulnerable rubber O-rings and multiple seals in favor of a single welded joint. Innovative techniques are sought that would allow any of the following:

- Bonding of graphite and ceramic parts to stainless steel, aluminum, titanium, or other metals or bonding of ceramic parts to graphite where the joint is capable of sustained high-and/or low-temperature operation.
- Bonding of very dissimilar metals such as molybdenum-aluminum, titanium-aluminum where the joint is capable of sustained high-and/or low-temperature operation.
- Construction of low-resistance, graphite-metal joints capable of operation at temperatures in excess of 1000°C.

**References:**

Intrater, J., "The Challenge of Bonding Ceramics to Metals" in Machine Design Magazine (Penton Publishing, Cleveland) 61, 95-100 (1989). ISSN 0387-1045

Twentyman, M.E., Hancock, P., "High-Temperature Metallizing of Alumina" from Surfaces and Interfaces in Ceramic and Ceramic-Metal System, J. Park and A. Evans (eds.) Plenum Press, New York, 1981, pp. 535-546. ISBN 0-30-640726-4

Donnelly, R.G., and Slaughter, G.M., "The Brazing of Graphite" in Welding Journal 41 (1962) reprinted in the Source Book on Brazing and Brazing Technology, ASM Int., Materials Park, OH (1980), pp. 308-314. ISBN 0-87-170099-9

## 04.26 Methods For Joining Carbon-Carbon Composites and High-Temperature Metals

Center: LaRC

Innovations are needed in the area of joining carbon-carbon composite materials to selected high-temperature metallic materials such as titanium alloys, superalloys, and refractory metals. Joining methods which result in permanent material bonds are of interest as opposed to those relying on mechanical fastening. Needs exist for joining to both coated as well as uncoated carbon-carbon composites. The service environments of primary concern encompass the temperature range from 550°C to 1650°C depending on the temperature capability of the metal. Specific applications of interest include thin-walled metal tubes embedded within or joined to the carbon-carbon composite. The selected metals must be compatible with hot, high-pressure hydrogen.

**References:**

National Center for Advanced Technologies: National Advanced Composites Strategic Plan, Carbon-Carbon Composites, Symposium Draft, December 1990.

Bogowitz, R.G., and Metcalfe, A.G., Improved Brazing Technique for Pyrolytic Graphite. NASA Tech Brief No. 71-10293, August 1971.

Dadras, P., Joining of Carbon-Carbon Composites by Using $MoSi_2$ and Titanium Interlayers. The 14th Conference on Metal Matrix, Carbon, and Ceramic Matrix Composites, Cocoa Beach, FL, January 17-19, 1990. NASA CP-3097, Part 2, pp. 443-454.

# 05.00 Teleoperators and Robotics

## 05.01 Mission Support Flight Robotics

Center: MSFC

Long-duration on-orbit experiments require adaptive telerobotic systems for in-situ support of test operations. To conduct science experiments with the aid of laboratory-rack size telerobots, innovative concepts are needed in the following areas:

**Telepresence interface** for a small robotic arm within a space laboratory rack to allow experiment monitoring, and modifying of the robot and instruction sets. It should accommodate black and white and color cameras, include graphics, allow manual station- controlled, track blinking infrared targets, and be capable of computer control.

**Robotic path planning** that allows a mobile robot to navigate a complex trajectory. Acquisition and tracking of objects for recognition and three-dimensional perception in cluttered environment and proximity sensing for collision detection and avoidance.

**Robotic control algorithms** for flexible arms joining large payloads in space with minimal stabilization. These algorithms should include guidance of arm's payload from a remote sensor in a different reference frame, smart-joint controllers and remote operator stations.

**Remote system control** through shared, automated and manual methods. Remote recovery or path alteration via high-level operator control. Interactive graphic simulations of remote task with time-delay and visual parameters. Real-time operator presentation of sensors and three-dimensional audio target tracking, as well as development of anthropomorphic input devices and sensored end effectors.

**Miniature video cameras:** intelligent, non-interfering, proper spectrum, micro-G; lighting and guides for small specimens.

**References:**

'Physical and Digital Simulations for Space Robotics', Elaine Hinman, Gary Workman. International Robotics and Vision Automation Show and Conference. October, 1991.

## 05.02 Supervised Autonomous Intelligent Robotic Systems for Manned Space Missions

Center: JSC

NASA is interested in innovative space robotic systems that can perform tedious, time-consuming tasks autonomously to free the cognitive and dexterous skills of the crew for research and exploration in the space environment. Such systems must minimize the need for ground controllers guiding robots through intricate activities and avoid the resultant problems involved in communicating over the long distances of space. These systems should also provide enhanced safety for humans in space by performing dangerous tasks and provide rescue capability such as the EVA Retriever.

The focus of this subtopic is on the development of both software and hardware, including innovative CASE-like tools for the development and integration of autonomous system modules, and methods for the validation of dynamics control strategies in robotic testbeds. Additionally, projects are sought that develop innovative architectural designs for supervised autonomous robotics and the supporting technology for systems modules including:

- Greater mobility and capacity for manipulation.
- Fault-tolerant systems and mechanisms.
- Real-time collision avoidance with attached payloads in cluttered environments.
- Space-certifiable miniature servomotors.
- Human-robot two-way interfaces including voice and enhancing human understanding.
- Environmental modeling.
- Reasoning including planning.
- Control, including dynamical control via distributed processing chips.

**References:**

IEEE Transactions on Systems, Man, and Cybernetics November/December 1989, Volume 19, Number 6, 'Special Issue on Machine Vision'. AVAIL:AIAA

IEEE Transactions on Systems, Man, and Cybernetics November/December 1990, Volume 20, Number 6, 'Special Issue on Mobile Robotics'. AVAIL:AIAA

## 05.03 Miniature Space Manipulator

Center: JPL

The next generation of science experiments in space will use a manipulator within an experiment to actively control the experiment while it is in progress. The principal investigator, located on the ground, would use a graphics workstation to control the experiment.

Innovative developments are needed on the miniature manipulator mechanisms.

The general size of the manipulator should be about 20 cm. or smaller. The manipulator would require six or more degrees of freedom, include a miniature gripper, contain a force sensor, and include a multi-sensor communications multiplexing system. For such a small manipulator system, the wiring needs to be limited to wireless interfaces except for power and data. Electronic modules must communicate with the brushless dc motors, resolvers, quad-encoders, proximity sensors, grippers, and cameras. The electronic modules would connect to a data bus running through the manipulator. Imbedded microsensors could provide diagnostics and health monitoring.

**References:**

Backes, P. G., 'Ground-Remote Control for Space Station Telerobotics with Time Delay', American Astronautical Society Guidance and Control Conference paper AAS 92-052, Feb 10, 1992.

## 05.04 Space Robotic Mechanisms

Center: GSFC

This subtopic solicits novel concepts for the following:

**Transponders** that permit multiple signals to be passed back and forth between a robot's end-effectors and the robot proper; between robot joints; between the power-data fixture on the spacecraft or satellite; and between a payload and its host spacecraft or satellite. These transponders must be non-contact, EMI resistant, simple, compact, and suitable for use in outer space and permit a high data rate. This technology should be considered as a basis for a replacement for ordinary electrical and/or fiber optic connectors. The portion of the transponder that is exposed to outer space should be designed such that insertion and separation forces are minimal and precision alignment and protective covers are not required.

**Transmissions** for robot joints are needed that are strong and compact and have a large mechanical advantage. These must be precision and anti-backlash.

**Fastening systems** for payloads and other mating members (trusses, orbital replacement units).

**A high-fidelity, off-loading system** for testing space robots in a near zero-gravity environment. This device must physically permit a six degree-of-freedom space robot to be tested and exercised on earth in an end-to-end configuration.

**A micro-miniature six degree-of-freedom precision stage** for adjusting small, light devices, such as mirrors. The use of ultrasonic motors should be considered.

**Mechatronic electric motor systems** including compact, efficient rotary and linear systems. Techniques are needed that use micro-miniature sensor-on-a-chip technology, embedded into motor/transmission systems, to allow modern microprocessor technology control of these devices with extraordinary precision. The technique also allows series-wound motors to emulate the control characteristics of other motor configurations: e.g., shunt, compound, synchronous, variable flux or dc brushless.

**References:**

Vranish, J.M., 26th Aerospace Mechanisms Symposium, [Spline-Locking Screw Fastening Strategy (SLSFS)], NASA & AIAA, NASA/GSFC, Greenbelt, MD, USA, May 20, 1992. N92-25074

Vranish, J.M., IEEE International Conference on Robotics and Automation [Space Robotics Research at the Goddard Space Flight Center], Tutorial S1 Intelligent Sensory Processing for Space Based Robotics, pp. 115-153, Sacramento, Calif., USA, April 6-13, 1991.
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Vranish, J.M., Sharifi, M., Second European In-Orbit Operations Technology Symposium, [NASA/GSFC Split Rail Parallel Gripper], pp. 383-7, Toulouse, France, Sep. 1989. N90-24328

## 05.05 Robotic Surrogates for Human Grasping and Manipulation

Center: JSC

Humans and robots must be capable of interacting with future space hardware. The robot must be capable of autonomous operation, teleoperation, or a combination of the two. It might be substituted for a human (e.g. in hazardous operations) or operate in conjunction with a human as an assistant. Dexterous robotic grasping and manipulation capability must be developed to achieve this capability. Innovations are required in the following areas:

- Human-scale, robotic hand designs for human-type grasping and manipulation.
- Human-scale robotic arm designs for grasping and manipulating objects by using the exterior surfaces of the arms, much like large fingers.
- Human-scale integrated arm, wrist, and hand designs for human-type grasping and manipulation.

- Object sensing, adaptive grasping, manipulation, or stable grasp recognition functions, as well as integration of sensors with a robotic arm, wrist, and hand to provide these functions.

- Tactile, slip, force, and torque sensing for a human-scale robotic arm and hand.

- Intelligent systems that exhibit higher-order human-like grasping and manipulation behaviors such as active, haptic (touch) exploration and object recognition, object pose (position orientation) estimation based on sensory feedback, adaptive vision-hand coordination, and learning-based arm and hand controls.

- Devices or systems that use a human arm, wrist, and hand as a master controller with bilateral control and sensing features. Easy donning, doffing, and portability are highly desirable features.

- Devices or systems to provide intuitive tactile, force, and torque feedback to a human operator's arm and hand.

**References:**

IEEE International Conference on Robotics and Automation, 7th, Proceedings, Vol. 1-3, Sacramento, CA, April 9-11, 1991. A92-21520

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Hess, et al., "Smart Hands for the EVA Retriever", Third Annual Workshop on Space Operations Automation and Robotics (SOAR '89), Proceedings, NASA Conference Publication 3059, Houston, TX, July 25-27, 1989. N90-25550CASI

## 05.06 Control Panel Robotic Cleaning End Effector

Center: KSC

Innovative robotic cleaning end effectors and/or methods are being sought that allow a robot to perform cleaning of sensitive control panels. The end-effector must be mounted to an existing robot interface plate. It will clean panels on equipment racks. Dust and fiber particles, grease, and oil must be removed from instrument panels with buttons, dials, switches, and video screens. The end-effector must function in a class 100 K clean room environment and remove any contaminants generated by the cleaning process. The weight of the end-effector should be as light as possible.

**References:**

Lee, C.S.G., Gonzalez, R.C., Fu, K.S., "Robotics" 2nd Edition; IEEE Computer Society ; IEEE Catalog Number EH0241-0. ISBN 08186-0658-4

## 05.07 Remote Measurement System for Robot Position

Center: KSC

Exact real-time knowledge of the position of a robot while it is moving is not available. Innovative methods are being sought to develop a system for real-time measurement of the position and orientation of the robot base and/or end-effector relative to a fixed coordinate system. The measuring system will be used with robots that must accurately position themselves in a large work area. The system should provide real-time data to the control system on the position and orientation of fixed points on the robot. It will eliminate the need for home position sensors and absolute and/or incremental encoders and measure position on start-up or recovery from a power failure.

The measurement system must be independent of the robot and measure the absolute spatial pose, three displacements and three rotations of the robot. The accuracy of the measurement should be approximately 1.5 mm and 0.1 degrees at 40 m. The data collection method should have an acquisition rate of approximately 100 Hz or better and provide RS232 data transfer. The system should be light-weight, easy to implement, and generic so it could be retrofitted on existing robots. Technologies such as radio signal triangulation, laser scanner, acoustic sensors, and other such remote measurement systems, should be considered.

**References:**

Lee, C.S.G., Gonzalez, R.C., Fu, K.S., "Robotics" 2nd Edition; IEEE Computer Society; IEEE Catalog Number EH0241-0. ISBN 08186-0658-4

## 05.08 Telerobotic Displays, Low-Disturbance Systems, and Non-Visual Sensing

Center: LaRC

New concepts are solicited for telerobotic guidance displays and telerobotic designs and controls that will minimize disturbances, prevent potential damage, and be intrinsically safe around humans. Small, lightweight, robust sensing methods are also sought. Areas of interest include:

**Guidance displays:** Visual display techniques for use with path planning systems that provide natural cues for real-time teleoperator trajectory control.

**Low Disturbance Systems:** Telerobotic systems that can reliably minimize interactive forces during telerobotic tasks would minimize disturbances to microgravity experiments, prevent inadvertent damage to adjacent structures, and enhance interaction with manned operations. Current systems are designed for high payloads and/or high rates, with actual rates and applied forces limited by the control system. Alternative concepts are sought such as new actuator concepts, manipulator mechanical designs, or control systems which are tolerant to multiple faults.

**Volumetric Sensing Methods:** Small, light-weight, low-power sensing methods are sought that can operate in vacuum, do not generate EMI, and can be carried by a small robot or mounted in end effectors, for proximity measurement, tactile sensing, force and/or torque sensing, for identifying materials properties, or for mapping three-dimensional surfaces. Methods for extending two-dimensional imaging data to volumetric measurements are sought. Both planar and curved surfaces would be scanned to detect and measure surface characteristics.

**References:**

Cooper, E.G., Jones, S.M., Goods, P.W., and Vazquez, S.L., Automated Anomaly Detection for Orbiter High Temperature Reusable Surface Insulation. SPIE OE/Technology Conference, Boston, MA, November 15-20, 1992.

# 06.00 Computer Sciences and Applications

## 06.01 Computational Advances for Aerospace Applications

Center: ARC

New concepts are solicited to improve and enhance computational techniques for solving large-scale scientific and engineering problems in many aerospace disciplines. Improvements include increased computational speed (operational rates on the order of billions of floating point operations per second on arrays of several million elements), graphics, and all aspects of data handling including storage and long-haul communications. Proposals may address any of the following areas:

**Parallel processing.** Methods and software for exploiting parallel processing and for easing the task of developing efficient FORTRAN-based programs for parallel processing computers while retaining the efficiency of programs transferred from one architectural design to another; also methods for predicting resulting system performance prior to system construction. Architectures of interest include multiple instruction-stream multiple data-stream (MIMD), systolic arrays, data flow, demand driven and reduction machines.

**Data management.** Software and hardware systems to manage, structure, and handle large scientific and engineering computation databases, including systems to facilitate the preparation of data input (particularly complex grid systems) and the analysis of results interactively, using graphic engineering workstations networked to supercomputers, new or enhanced data storage, and data compression techniques.

**Graphics.** Computer graphics concepts capable of implementation in software and hardware for visualizing complex computational results to bring new understanding to the physical phenomena being modeled, with emphasis on displaying and recording (e.g, video, multimedia, etc.) of several physical quantities varying over three dimensions and time. For example, enhanced depth perception display of internal flow structures, quantitative comparison of numerical and experimental fluid flow data; solid modeling of aerospace configurations for computer animations, grid generation, and digital image processing techniques applicable to surface, tracer, and optical flow visualization methods; and high-speed but cost-effective image processing techniques suitable for analysis and synthesis of fluid dynamics data.

**References:**
Cheng, Doreen Y., "A Survey of Parallel Programming Tools," NASA Ames Research Paper, January 23, 1991. AVAIL:CASI

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ISBN 0818620560, ISBN 0897914120

Yan, Wen-Jei, "Handbook of Flow Visualization," Ann Arbor, Hemisphere Publishing Corporation, 1989. ISBN 0891166696

Peterson, Victor L., et al., "Supercomputer Requirements for Selected Disciplines Important to Aerospace," Proceedings of the IEEE, Vol. 77 (July 1989), No. 7. A89-53152

## 06.02 Software Support Systems for Unmanned Missions

Center: GSFC

The software engineering of the large-scale computer systems, needed for increasingly complex ground support for unmanned scientific spacecraft missions, places increasingly heavy demands on both managers and developers. Innovations are sought which will result in:

- More cost-effective management of the software engineering process resulting from, for example, continuous improvement programs and metric-based techniques for the development, evaluation, and/or acquisition of software system components.
- Increased productivity resulting from new, alternative, software engineering paradigms such as development by software reuse and graphical and/or iconic approaches to programming.
- Improved software performance, reliability, and fault tolerance in critical spacecraft ground system components.
- Advancements in ground system architectures in support of distributed operations.
- Knowledge-based support for human operators in spacecraft command and control environments through use of improved human-computer interface/interaction techniques, intelligent tutoring, artificial intelligence, agent-oriented, and virtual reality techniques.

**References:**
"Artificial Intelligence Costs, Benefits, and Risks for Selected Spacecraft Ground System Automation Scenarios," Walter Truszkowski, Barry Silverman, Martha Kahn, Henry Hexmoor, Telematics and Informatics, Vol. 5, No. 3, pp. 163-177, Pergamon Press, 1988. A89-21803

"Launching AI in NASA Ground Systems," Dorothy Perkins, Walt Truszkowski, AIAA and NASA International Symposium on Space Information Systems, Pasadena, CA, 1990, AIAA Paper No. 90-5055. A91-14977

"A Learning-Based Software Engineering Environment for Reusing Design Knowledge," Sidney Bailin, Robert Gattis, Walt Truszkowski, Internal Journal of Software Engineering and Knowledge Engineering, Vol.1, No. 4, pp. 351-371, 1991 World Scientific Publishing Co.

"CC2005 An Architecture for Future Mission Operations Centers," Loral Aerosys, LAS-AISS-0003, October 1992.

## 06.03 Reliable Software Development

Center: JSC/LaRC

Innovative approaches are sought for developing and verifying highly reliable software for safety-critical aerospace applications. Approaches include computer-aided support of requirements analysis and design specification, executable specification languages, automatic program generators, programming language features to improve software reliability, automated testing and verification techniques, and software safety and risk assessment methods. Of particular concern are programming languages and environments for developing time-critical applications, distributed and parallel software, and fault-tolerant software. Potential applications extend across all NASA activities.

**References:**
Proceedings of Digital Avionics Systems Conference 11, Seattle, Washington, October 5-8, 1992, IEEE Catalog No. 92CH3212.

Proceedings of TRI-Ada 92, Orlando, Florida, November 16-20, 1992.

Proceedings of AIAA Computing in Aerospace 8 Conference, American Institute of Aeronautics and Astronautics, Baltimore, Maryland, October 21-24, 1991.

Schepper, Charlotte, and Kathryn Smith, ed., A NASA-Wide Approach Toward Cost-Effective High-Quality Software Through Reuse, CP10115, January 1993.

## 06.04 Knowledge-Based Systems for Aerospace Applications

Center: ARC/JSC

The first generation of knowledge-based systems has proven enormously useful in many areas of monitoring, diagnosis, and data analysis. Innovative methods in several areas are solicited to create a second generation of expert systems applicable to even broader applications in aerospace in areas such as:

**Design and diagnosis of physical devices**--systems for preserving a practical "corporate" memory of the multisite design of complex devices and for using that knowledge for re-design and diagnosis throughout the device lifecycle. Model-based or qualitative reasoning approaches are of considerable interest.

**Planning and scheduling**--particularly work in reactive systems usable in a variety of manufacturing processing applications.

**Automated data analysis**--of both telemetry data from complex and aerospace vehicles and platforms, and science data from the whole range of space science missions. Innovations in machine learning are particularly encouraged.

References:


Berenji, H.R., Chen, Y.Y., Lee, C.C., et al.,"A Hierarchical Approach to Designing Approximate Reasoning-Based Controllers for Dynamic Physical Systems. Proc.," 6th Conf. on Uncertainty in Artificial Intelligence, 362-369, 1990. AVAIL:ESL

Boy, G.A., and Mathe, N.,"Operator Assistant Systems: An Experimental Approach Using a Telerobotics Application," IJCAI Workshop on Integrated Human-Machine Intelligence in Aerospace Systems, Detroit MI, August 21, 1989; and in Internat'l Jour. Intell. Systems, Special Issue on Knowledge Acquisition, 1991. ISSN 0094-243X

Colombano, S.P., Young, L.R., Haymann-Haber, G., et al.,"An Expert System to Advise Astronauts During Experiments," 40th Congress Internat'l Astronautical Federation, Oct., 1989. A90-13266

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## 06.05 Software Systems for Mission Planning and Flight Control

Center: JSC

Innovative concepts are needed to improve pre-flight and real-time mission planning techniques for on-board and ground control support of manned flight operations. Areas of particular interest include:

- Fuzzy logic in the support of flight control and pattern recognition.
- Intelligent computer-aided training and virtual reality systems to support training development.
- Planning and scheduling tools including genetic algorithms.
- Failure detection technology including artificial neural systems.
- Human-machine interfaces including speech recognition and synthesis.

Innovative approaches may be in the form of building tools to facilitate the advancement of the technology and/or construction of demonstrations which illustrate the potential uses of the technology.

**References:**


Rufat, Watts, Carey, et al., "Distributed Cooperative Systems for Advanced Automation:Tradeoffs," In the Proceedings of the IEEE conference on Systems, Man, and Cybernetics, Los Angeles, CA, November 1990. A87-50632

Lea, R.N., "Automated Space Vehicle Control for Rendezvous Proximity Operations", Telematics and Informatics, Vol 5 (1988), No 3., 179-185. N88-30335

Villarreal, J., and Robert Shelton, R., "A Space Time Neural Network", Second International Conference on Neural Networks and Fuzzy Logic, Houston, TX, 1990. AVAIL:ESL

Loftin, R.B., et al., "An Intelligent System for Training Space Shuttle Flight Controllers in Satellite Deployment Procedures, Machine-Mediated Learning," Vol. 3 (1989), 41. A89-21802, N88-30331


## 06.06 Optical Processing Technology

Center: ARC

NASA has an on-going need for novel processing architectures to address mission-related problems in which speed, weight, and power consumption are critical issues. Specific application areas include robotic vision, autonomous lander guidance, and spectral data analysis. Optical processing technology shows promise in such areas by taking advantage of the speed and inherent parallel nature of light to perform computations more quickly and with less power than can be accomplished with traditional digital electronics. A major bottleneck, however, is due to the limitations of commercially available spatial light modulators (SLMs). Processing architectures which use to their fullest the advantages of photonics over electronics require spatial light modulators that combine high-resolution, high-speed updatability, and high-contrast phase and/or amplitude modulation. Currently available SLM devices offer some of these features but are often the result of a trade-off between resolution and speed.

This subtopic solicits improvements in spatial light modulator devices for use in optical processing architectures, specifically in the area of combining high-resolution and high-contrast with high-speed updatability. Multi-level phase or amplitude modulation is desirable, but not necessary. Both electrically and optically addressed devices should be considered.

**References:**


Warde, C., and Fisher A.D., "Spatial Light Modulators: Applications and Functional Capabilities in Optical Signal Processing," Academic Press, San Diego, (1987) 477-523. A90-26837, N90-11804

## 06.07 Virtual Reality Systems for Crewed Spacecraft and Telepresence Applications
Center: JSC

Virtual reality (VR) is a display technology that could be utilized to investigate and develop robotic teleoperations and telepresence capability for applications not only for Shuttle and future manned spacecraft but also in space exploration. A major objective is to develop state-of-the-art hardware and software compatible with commercial systems and that integrates within the VR architecture currently under development in JSC's Integrated Graphic Operations and Analysis Laboratory (IGOAL) in order to evaluate the full potential for low-end, cost-effective VR simulation applications. The basic IGOAL graphic architecture was developed by JSC under the name Object Orientation Manipulator (OOM) and is available through COSMIC. Various potential applications of object orientation manipulation include:

- EVA part-task training and task familiarization.
- Integrated EVA/Shuttle Remote Manipulator System (RMS) operations analysis and timeline development.
- Simulation data post-processing and display.
- Orbiter and future manned spacecraft viewing analysis.
- High fidelity graphic environments for telerobotic operations development.

Emphasis is placed on "low-end" and "cost effective" simulation hardware and software enabling desktop simulation capability that can be replicated at a reasonable cost, that doesn't require an excessive number of computer specialists to operate, and that enhances, not replaces current capability. The VR system should allow development of and interaction with graphical representations of actual physical configurations that are not artificially limited by test-facility-imposed physical constraints.

**References:**

Gott, C.J., et al., "A Space Systems Perspective of Graphics Simulation Integration", Proceedings of the Workshop on Space Telerobotics, Pasadena, CA, July, 1987, JPL Publication 87-13, Vol. II. N89-26522

Dyer, D., (1990), A Dataflow Toolkit for Visualization. IEEE Computer Graphics and Applications, 4, 60-69. ISSN 0272-1716

Upson, C., et al., (1989), The Application Visualization System: A Computational Environment for Scientific Visualization. IEEE International Conference on Robotics and Automation, 1752-1757. A89-53401

## 06.08 Model-Based Reasoning for Diagnosis and Control
Center: KSC

The use of model-based reasoning techniques for diagnosis and control of real-time systems has been proven. Automation of many processes associated with developing and maintaining models for these systems can enhance and enable the formation of an intelligent, integrated spacecraft processing environment to improve all phases of life-cycle development of spacecraft and reduce life cycle costs. Methods are being sought to:

- Automatically generate control procedures or operations scripts from operations and maintenance instructions.

- Automatically identify and model system parameters that describe system behavior related to non-physical system components, such as flows, from system schematics.

- Automate the synchronization of models by identification and adjustment of components.

- Integrate hypermedia techniques with human-computer interface displays to enhance user visibility into system operations.

**References:**

Pepe, C., et al., "KATE - A Software Description and Project Overview", (March 1992).

Belton-Parrish, C.L., and Enand, S., "Kate - A Model-based Diagnostic and Control Shell", Intelligent Diagnostic Systems, Eds. Martin, K.F., Williams J.H., and Pham, D.T., IFS/Springer-Verlag, (1992).

Scarl, E.A., Jamieson, J.R., and Delaune, C.I., "Diagnosis and Sensor Validation through Knowledge of Structure and Function", IEEE - Transaction on Systems, Man and Cybernetics SMC-17 (3), pp. 360-368 (May/June 1987).

Compilation of Publications (1987-1990) on "Automated Knowledge Generation", Department of Computer Engineering, University of Central Florida, Orlando, FL, NASA Grant #NAG10-0042.

## 06.09 Data Fusion and Modeling of Atmospheric Photochemical Phenomena
Center: GSFC

Innovative concepts are solicited for upgrading and extending computational abilities and techniques for modeling atmospheric photochemical systems. The Voyager mission, plus ongoing NASA supported ground-based observations, have returned a wealth of information about photochemically produced species in the atmospheres of the outer planets and Titan. Additionally, the NASA/ESA Cassini mission to Saturn and Titan requires updated and expanded models to aid in sequence planning and the interpretation of the returned data. The outer planets and Titan share many similarities in their photochemical systems, allowing for a flexible model to be adapted to each object with minimal fine tuning. Innovations are needed in the following areas:

**Complex Systems Modeling:** Extend current photochemical models to allow for increasingly complicated reaction processes, physical processes, and realistic atmospheric dynamics models, while remaining suitable for usage on individual workstations. Code structures must be modular, flexible, and amenable to continual updating and sensitivity studies. Developed codes will adhere to operational standards.

**User Accessibility:** Interface packages to set up, execute, and interpret the results of the current photochemical modeling and analysis codes. Emphasis should be on techniques that enhance data visualization (the ability to graphically display user selected output), menu driven input system (allowing for easy selection of input parameters), conformity to standard GUI (e.g. X-Windows, Motif, etc.) and lowering the requisite knowledge level of users (analyst vs. scientist).

**References:**

Kostiuk, T., Romani, P., Espenak, F., and Bézard, "Stratospheric ethan on Neptune: Comparison of ground based and Voyager IRIS retrievals." Icarus, 99, 353-362, 1992. A93-14902

Bézard, B., Romani, P.N., Conrath, B.J., and Maguire, W.C., "Hydrocarbons in Neptune's stratosphere from Voyager infrared observations." JGR Supp., 96, 18961-18976, 1991. A92-11906

Kostiuk, T., Espenak, F., Romani, P., and Mumma, M.M., "Infrared studies of hydrocarbons on Jupiter," Infrared Phys., 29, 199-204, 1989. A89-44981

## 06.10 Librarian for Reusable Software

Center: GSFC

Increasing demands for producing software more cost-effectively, with higher quality and in less time, have led to increasing the reusability of existing software source components. By reusing previously proven algorithms and software, the design, coding, and unit test phases of development can all be significantly reduced. Reusable software components achieve higher quality due to the repeated testing applied each time a component is reused. In addition, prototyping becomes more advantageous in terms of both cost and time. Some of the major difficulties to achieving significant reuse of existing software components are identifying potentially reusable components for inclusion in a library, methods to represent software component functionality, storage schemes, and the user's ability to locate and retrieve components with the desired functionality. Innovative proposals are sought to address the issues relating to representation, indexing, storage, and retrieval of reusable software source components.

**References:**

Caldiera, G., and Basili, V.R., "Identifying and Qualifying Reusable Software Components," IEEE Computer, Vol. 24, No. 2, February 1991. ISSN 0018-9162

Prieto-Diaz, R., and Freeman, P., "Classifying Software for Reusability," IEEE Software, Vol. 4, No. 1, January 1987. ISSN 0740-7459

Maarek, Y.S., Berry, D.M., and Kaiser, G.E., "An Information Retrieval Approach for Automatically Constructing Software Libraries," IEEE Transactions on Software Engineering, Vol. 17, No. 8, August 1991. ISSN 0018-9391

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# 07.00 Information Systems and Data Handling

## 07.01 High-Performance Computing and Communication Information Exchange

Center: GSFC

While the High-Performance Computing and Communication (HPCC) program deals with "inter-computer" communications, it is also important to deal with "inter-human" communication, in particular, among the many HPCC program participants. The objective of the HPCC Distributed Information Exchange project is to provide an information exchange facility in which the types of information shared include software, data, bibliographics, documents. In consequence, NASA is looking for innovative products in repository management systems, user-access tools to heterogeneous distributed repository systems, and tools for managing standards that support the following repositories:

**Software repositories** used to maintain on-line software packages and programs.

**Data repositories** used to maintain on-line data datasets and databases. Mass storage systems are also of interest.

**Bibliographic repositories** used to maintain on-line journals and books.

**Document repositories** used to maintain on-line document collections and reports.

**References:**


Grand Challenges: High Performance Computing and Communications. A Report by the Committee on Physical, Mathematical and Engineering Sciences To Supplement the Presidents Fiscal Year 1992 Budget. N92-18767

Grand Challenges: 1993 High Performance Computing and Communications. A Report by the Committee on Physical, Mathematical, and Engineering Sciences To Supplement the Presidents Fiscal Year 1993 Budget. N92-30600


## 07.02 Computational Applications Software for Massively Parallel Computing Systems

Center: GSFC

NASA has a growing need for high-rate, ground-based computer systems to perform multidisciplinary numerical modeling of physical systems and analyze large volumes of acquired data and model data. Many of these applications execute rapidly on massively parallel computing architectures that offer the potential of scalability to teraFLOPS performance in the 1990s and cost-performance ratios significantly better than conventional vector supercomputers. Large-scale, massively parallel systems are now available commercially including Thinking Machine's CM-5, the MasPar's MP-2, and the Intel Paragon.

Extensive availability of applications software packages are needed for the commercial massively parallel systems so users can accomplish productive work rapidly. Packages desired are similar to those currently found on large-scale vector processors and include:

- Computational fluid dynamics for geophysical and space physics application.
- Particle techniques for astrophysics applications.
- Sensor data analysis algorithms.
- Graphics generation and data visualization.
- Image processing and pattern recognition.
- Mathematics and statistics algorithms.
- Database management.
- Artificial intelligence as an aid to data analysis.
- Optimization problem algorithms.
- Image restoration techniques (characterized by spatial and spectral varying point-spread functions).

**References:**


Proceedings of Frontiers '92 - 4th Symposium on the Frontiers of Massively Parallel Computation," IEEE Computer Society Press Catalog #2772-02, October 1992. ISBN 081867727


## 07.03 Information Processing Technology and Integrated Data Systems

Center: LaRC

High-performance, fault-tolerant, distributed information data systems are needed for advanced aerospace missions. They must be capable of providing data communication bandwidths and processing services well above what is available for today's spacecraft and aircraft, particularly for data systems that have an integrated form where video, voice, and data are simultaneously distributed and processed. These data systems may carry real-time data; therefore, both delays and variability of delay must be kept to a minimum for correct operation. For higher-level communications and processing functions, the delays and variability are dominated by the distributed operating system; for lower-level communications and processing, they are dominated by the physical properties of the hardware implementation. Innovations are sought in both distributed systems and hardware implementation for meeting future high-performance data system needs, including:

**Distributed system** concepts and implementations for high-performance, real-time response and fault tolerance.

**Network architecture** and topology forms that enhance performance and fault tolerance.

**Distributed, secure,** fault-tolerant computation and control algorithms.

**Electro-optical and optical nodes** for network control and high-performance interfaces to the network.

**Optical and electro-optical components and devices** (fibers, waveguides, couplers, switches, transmitters, receivers, amplifiers) for optical networks.

**High-performance processors and computers** as elements of distributed systems.

**Simulation and modeling tools** to evaluate candidate multiprocessing and distributed data systems.

**Components, devices, and systems** for high-performance, erasable, optical disk recorder.

**References:**

Husain, A., et al., Optical Processing For Future Computer Networks, SPIE Optical Engineering, Vol. 25, No. 1, January, 1986. A86-21973

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## 07.04 Spatial Data Management and Geographic Information Systems

Center: SSC

Currently, remotely sensed data and geographic information system (GIS) technologies are employed to solve a wide range of spatially related problems including urban infrastructure planning, natural resources management, and environmental monitoring. Although advanced techniques exist for the analysis of remotely sensed data with other spatial data for improved information, sophisticated links between these data and existing or new environmental models are limited. Furthermore, such technical issues as the incorporation of expert systems technology, advanced graphical user interfaces, data structure conversion, and data storage are fundamental areas of investigation for improving the use of environmental models. Innovations are sought in such areas.

**References:**

Robinson, V.B., Frank, A., 1987, "Expert Systems for Geographic Information Systems," Photogrammetric Engineering and Remote Sensing, Vol. 53 (1987), No. 10, 1435-1441. EI 881004257

Smith, T.R., Menon, S., Star, J., et al., "Requirements and Principles for the Implementation and Construction of Large-Scale Geographic Information Systems," International Journal of Geographic Information Systems, Vol. 1 (1987), Number 1, 13-31. A88-28684

Gibson, L., and Lucas, D., "Vectorization of Raster Images Using Hierarchical Methods," Computer Graphics and Image Processing, Vol. 20 (1982), 82. EI 8301003294

Ripple, William J., Ulshoefer, V., "Expert Systems and Spatial Data Models for Efficient Geographic Data Handling," Photogrammetric Engineering and Remote Sensing, Vol. 53 (1987), No. 10, 1431-1433. ISSN 0099-1112

## 07.05 Automatic Contour Vectorization Software

Center: HQ

Although a number of automatic vectorization software packages are commercially available, they are "multipurpose" programs designed to generate vector-line data from raster binary or continuous-tone raster data for all kinds of applications. However, their output is less than optimal for contour lines which require many hours of editing before a usable product is obtained. Innovations are sought for the development of a highly automated, analog-to-digital conversion of contour maps. Automatic contour vectorization software requires such attributes as:

- Characteristics of contour lines and maps are fully utilized to generate continuous, undivided contours.
- Primary, secondary, approximate, carrying contours, elevation labels, and spot elevations are recognized, resolved, and stored as different sets.
- Software is modular, easy to integrate with other application programs, highly portable, and able to run on off-the-shelf, inexpensive hardware.

**References:**

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Ramirez, J.R., Lee, D., The Development of a Cartographic Model for Consistent and Efficient Map Production, The Ohio State University Center for Mapping, Final Report, U.S. Geological Survey Grant No. 14-08-0002-G1884, 1991.

## 07.06 Heterogeneous Distributed Data Management
Center: JSC

Due to the great volume of objects available for retrieval across networks, such as the Internet, NASA is interested in information retrieval system components that provide ranking of those objects according to an optimal order. For example, given a query, a system with the desired components should respond by showing not only documents, but also video, photographs, or any other data relevant to the stated request. The system should also be capable of delivering the output products in the order of value to the query, as opposed to an undifferentiated response. Moreover, the properties of this ordering of objects should be such that they reflect psychometrically measured preference functions of the query submitter. A desirable component will therefore integrate this preference measurement function within a "user customizable" query interface mechanism. Of particular interest are components utilizing ANSI Z39.50 protocol with wide-area information server (WAIS) architectures. Products envisioned to arise from this effort are executable "daemons" (friendly embedded programs), which may be incorporated into UNIX systems environments and called from ANSI "C" language compilers.

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## 07.07 Scientific Data Visualization
Center: JPL

There is an increasing need to develop innovative tools and techniques that enable more effective communication between the scientist and data. Scientific visualization is a process whereby scientists communicate with data by manipulating its visual representation during processing. This method of computing transforms the symbolic into the geometric, enabling scientists to observe their simulations and computations. Visualization unifies computer graphics, image processing, computer vision, signal processing, user interfaces, high-speed computing, and high-speed communications.

NASA needs integrated families of tools and procedures for interactively visualizing and manipulating science data and models and for innovative concepts for displaying complex multidimensional, multivariate data types. Specific areas of interest include:

- Techniques and software for interactive three-dimensional animation of multidimensional data sets of different origin, resolution and structure.
- Tools and techniques to interactively build and manipulate complex scientific models and merge these models with data.
- Graphical user interfaces that support,data visualization constructs including data navigation, model building and control, data scaling and transformation.
- Techniques and software for visually simulating instrument observations including interactive manipulation of instrument and observational parameters.
- Virtual environments that explore and exploit the touring paradigm for data interrogation, manipulation, and interpretation.

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## 07.08 Data Capture and Display Using Holographic Techniques
Center: SSC

Present techniques for capturing visual scenes and storing and displaying data, which might be done by electronic systems, do not use holography. Those visualization schemes that are of a holographic nature use photographic film which is not directly achievable as electronic data, i.e., digital data. This subtopic addresses electronic methods and equipment that could capture and store the necessary fourier transform data from one data set, with the potential to combine multiple display data sets, to reconstruct the hologram. This system must then be able to display the hologram in a three-dimensional or solid appearing projection.

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## 07.09 On-Board Information Processing for Autonomous Navigation

Center: JPL

Planetary exploration will require more sophisticated and autonomous onboard navigation systems and aids for both micro-spacecrafts and micro-rovers. Furthermore, added constraints on earth dependence include limited power resources and communication bandwidth for transmission of data and/or images critical to navigation. Enhanced onboard information processing for autonomous navigation will require a low-power neural network hardware consisting of an integrated focal plane image compression system capable of real-time (video-frame rate) lossy image compression (encoding). Such a system would be comprised of a CCD sensor array front-end module linked directly to an image encoder processor module (along with any necessary digital support logic).

Phase I should specifically address the feasibility of, but not be limited to, the image encoder system, including requirements for low power compression and the possible use of analog neural network VLSI techniques.

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## 07.10 Formal Methods for the Design of Flight-Critical Systems

Center: LaRC

Modern civil aircraft depend on digital computer hardware and software in flight-critical systems. For U.S. manufactured aircraft to remain both safe and competitive, such systems must meet stringent reliability requirements. A digital system may fail as a result of either a physical failure or a design error. Much progress has been made in developing methods to accommodate physical failures, but design error remains a serious problem. In fact, the quantification of reliability in the presence of design flaws has been shown to be infeasible, whether applied to hardware or software (standard or fault-tolerant). The only way by which the desired reliability requirements can be met is the elimination of design errors.

Formal methods offer great promise for the elimination of design errors. Just as calculus and differential equations provide rigorous mathematical tools for design and analysis in other engineering fields, formal logic can provide rigorous mathematical tools for design and analysis of digital systems. Although the theoretical appeal of formal methods is strong, much work remains to be done to enable the practical, cost-effective use of formal methods by the aerospace industry. This subtopic solicits innovative techniques and tools towards that end, particularly:

- Integrating formal methods with existing methods, tools and languages
- Training engineers to use formal methods effectively
- Formal specification languages
- Theorem provers and proof checkers
- Visual languages and tools with complete, formal semantics

**References:**
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# 08.00 Instrumentation and Sensors

## 08.01 Topographic Measurements from Space
Center: GSFC

High-resolution topographic mapping of the Earth, lunar, and planetary surfaces from spacecraft requires major improvements in the laser altimeter sensors. Sensor technology goals include an increase in laser transmitter performance and electrical efficiency, receiver sensitivity, laser pulse pointing angle knowledge, and sensor compactness and ruggedness. Innovations are required in laser transmitters, optical receivers, and attitude sensors in order to ensure high signal-to-noise and range precision for each laser pulse measurement of range between the spacecraft and the planetary surface. Earth-based laser altimeter sensors equipped for autonomous operation from high-altitude aircraft require similar improvements. The technology challenges of space-based and high-altitude airborne laser altimetry include:

- A diode-pumped, solid-state laser transmitter that produces a minimum of 20 millijoules pulse energy in a short pulse (~2 nsec) in the wavelength region of 700 nm to 1100 nm with 10 percent or greater electrical-to-optical efficiency in a single transverse mode.

- An altimetry pulse receiver that is based on a silicon avalanche photodiode detector and provides 1 nWatt sensitivity or better in the detection of 2 nsec wide Gaussian pulses.

- An altimetry laser source that is based on short pulse (< 10 nsec) operation of AlGaAs or InGaAs diode laser emitters and produces peak transmitted laser power greater than 1 kWatt per pulse.

- A compact device, such as a CCD star camera or fiber-optic gyro, to measure laser pointing angles and propagate a pointing attitude estimate to an accuracy of 100 arc sec or better.

**References:**


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Bufton, J.L., "Laser Altimetry Measurements From Aircraft & Spacecraft," Proceedings IEEE, Vol.77, No.3 (1989), 463-477. A89-41691


## 08.02 Airborne, Remote, Turbulent-Air Motion Measurements
Center: LaRC

Innovations are needed to design, build, and test an airborne, remote, air-motion measurement system. The remote sensing system would be intended for, but not limited to, applications involving the measurement of the three-component ambient turbulent wind field in the daytime convective boundary layer (CBL). Remote measurements of the turbulent wind field made in front of the aircraft (~10m) would be correlated with available fast-response chemical species data obtained from in situ sensors located along the fuselage to obtain the horizontal and vertical flux, or transport, of the pertinent chemical species. Current in situ techniques for making turbulent three-component wind measurements are limited by: the influence of the air flow around the aircraft; a system calibration that is not based on physical constants; and an inability to make reliable measurements in clouds and in precipitation.

In addition to the capability for remote measurements forward of the aircraft, remote measurements of the turbulent wind field in the nadir and zenith directions from the aircraft would enable remote flux measurements to be attempted for those species for which remote lidar measurements are possible (i.e., aerosols, $O_3$, and water vapor). This capability would provide unique data on the troposphere-stratosphere exchange rates of these important species.

For applications in the CBL the proposed system must demonstrate respective measurement precisions of ±0.05 m/s and ±0.01 m/s for the vertical and horizontal wind components and have a horizontal resolution of less than 10 m in order to capture the significant levels of turbulence.

**References:**


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## 08.03 Instrumentation for Aerosol and Cloud Studies
Center: LaRC

Innovative improvements are solicited in sensor techniques, sensors, and sensor systems for ground-based, airborne, spaceborne monitoring of atmospheric clouds and aerosols produced naturally or from man's activities, including determination of:

- Vertical concentration profiles.
- Size-distribution from submicrometer to micrometer-size particles.
- Particle composition and morphology.
- Aerosol optical properties, spatial distribution, and fluxes.
- Ancillary atmospheric data required for analysis of aerosol properties.

New concepts might include lidars that operate at eye-safe wavelengths, in situ sensors capable of operating at stratospheric temperatures and pressures, and sensors that might have applications in environmental monitoring. Desirable attributes include reduced weight and power, greater reliability, greater resolution, and other significant figures of merit not currently achievable.

**References:**

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## 08.04 Climate Observations From Space
Center: GSFC

Satellite and supporting in situ observations of precipitation rates, cloud cover, and broadband radiation at the surface and top of the atmosphere are needed to satisfy global-scale climate monitoring requirements. This subtopic solicits innovative methods and techniques for the following:

**Measurement of rainfall** at the surface by improved direct and indirect techniques.

**Interpretation and assimilation of rainfall data** from weather radar and conventional observations including remote sensing algorithms and statistical techniques for applications of "ground-truth" measurements needed to validate satellite estimates of rainfall.

**Global monitoring** of spectral and broadband Earth radiation, surface radiation-budget, and radiation characteristics of clouds using both space platforms and ground-based observations.

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## 08.05 Optical Technology for Airborne Lidar Atmospheric Studies
Center: LaRC

Innovative developments are needed in optical technology to significantly expand the capability of active, remote sensing systems for airborne measurements of trace gas and aerosol distributions in large-scale atmospheric studies. Ozone and aerosol distributions in the troposphere and lower stratosphere and water vapor distributions in the lower troposphere are currently being measured with airborne lidar systems. Improvements in range, spatial resolution, and accuracy of these measurements are needed, and expanded measurement capabilities are required for water vapor in the upper troposphere and lower stratosphere and for ozone in the middle stratosphere. In addition, there is a need to measure other gases for atmospheric chemistry and dynamics investigations, such as carbon monoxide in the troposphere and nitrous oxide or methane in the lower stratosphere.

The innovation should enable:

- Extension of current airborne ozone, water vapor, and aerosol measurement capabilities in range, accuracy, and/or altitude regions.
- Profile measurements of new gas species to ranges of at least 8 km with requisite spatial and temporal resolution and accuracy.

- System and subsystem compatibility with aircraft environment and operation with minimum maintenance over at least 50 flight hours.

The innovations in optical technology could include new components (e.g., electro-optical devices, nonlinear crystals, optical filters, and detectors), subsystems (e.g., laser transmitters, optical receivers, and detector-amplifiers) or complete systems. Innovations could also address reduced weight, power, or measurement time; increased reliability, autonomy of operation, or measurement distance; or ability to measure gas and aerosol distributions over large concentration ranges.

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## 08.06 Airborne In Situ Water Vapor Instrumentation

Center: LaRC

An accurate depiction of the global distribution of water vapor in the troposphere and lower stratosphere has an important role in climate change studies. The dynamic range of water vapor concentrations encountered throughout the troposphere bridge several orders of magnitude and span atmospheric conditions ranging from the tropical planetary boundary layer (dew pt. ~ 30°C) to the arctic tropopause (frost pt. ~ -90°C). Current techniques used to obtain in situ airborne water vapor measurements do not have a sufficient dynamic range so that a single instrument could be used to obtain the required measurements over the specified altitude range.

Innovations are needed to design, build, and test compact airborne water vapor instrumentation that is capable of withstanding harsh and polluted operating conditions (e.g. commercial or research aircraft applications) and can provide repeatable measurements of water vapor concentrations encountered throughout the troposphere and lower stratosphere (0 - 3000 m). The instrument must have a frost/dew point measurement range of -90°C to 40°C with an absolute accuracy better than 5 percent and minimal operator interaction and service requirements. The instrument must be free from saturation and hysteresis effects and have a response time better than 1 Hz to satisfy temporal and spatial requirements imposed by airborne meteorological applications.

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## 08.07 Earth-Observing Sensor Development for Geostationary Orbit

Center: MSFC

Innovations are required for the development of a new generation of instrumentation for earth observation to be flown on the Geostationary Earth Observatory (GEO). The multi-sensor, multidisciplinary specifications of GEO will require significant improvements in spatial and spectral resolution relative to instruments that are presently on operational geostationary satellites. To meet the overall goals of NASA's Mission to Planet Earth, innovations for GEO are required in:

- Passive microwave systems, specifically large-aperture antenna systems, low-noise high frequency amplifiers, and multiple feed horn design for atmospheric sounding and sea surface and precipitation measurements.

- High-resolution visible and infrared imaging devices including advanced spectral separation techniques and high-performance focal plane arrays with on-board calibration.

- Thermally stable, large aperture (up to 1 meter diameter), high-resolution optical systems.

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## 08.08 Instruments for Measuring Atmospheric Composition and Environmental Pollution

Center: JPL

A new generation of light-weight instruments, to be flown on balloons and aircraft is required to measure trace gas abundance in the parts-per-billion and parts-per-trillion range. These instruments will measure the composition of the Earth's stratosphere and troposphere in order to understand the present conditions and susceptibility to change. They are part of a package of instruments that perform both in situ and remote sensing and utilize frequencies from the UV to the microwave. There is a pronounced need for instruments in the 10 - 30 kg mass range that would be used aboard smaller, easier-to-launch balloons as well as a light-weight, unmanned aircraft. Also sought are specialized instruments that could be flown aboard meteorological sounding balloons. The wavelengths or frequencies of primary interest are 200 - 400 nm, 2 - 18 microns, and 100 - 700 GHz.

A portable spectrometer is needed for the measurement, identification, and analysis of petrochemical contaminants within soils, alluvium, colluvium, and other rock materials. The most prominent approach at present utilizes gas chromatography, but this is slow and expensive, and is not well suited to use at remote sites. The object of the intended work would be to develop a cheaper, quicker, more reliable technology. A prototype instrument should include field portability, self calibration, preliminary data analysis and display capability, and approximate sensitivity of 10 ppm.

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## 08.09 Measuring Atmospheric Weather Parameters Using Active Remote Sensing

Center: GSFC

High-resolution, high-accuracy measurements of atmospheric aerosols, temperature, pressure, wind, and humidity from ground-based, aircraft and spacecraft platforms require improvements in the state-of-the-art, high-spectral-resolution, pulsed lasers; light-weight holographic scanning telescopes; and low-noise infrared detectors. Emphasis is on compactness, low weight, high reliability, and high efficiency. The technology challenges include:

- Compact, low-power, single-mode CW laser sources tunable between 760 - 770 nm with means for actively stabilizing the output to molecular absorption lines for injection seeding pulsed lasers.
- Low-pulse-energy, high-repetition-rate, narrow-linewidth laser sources in the 920 nm wavelength region for lidar measurements of water vapor.
- Geiger-mode, avalanche photodiode detectors with quantum efficiency > 10 percent in the 1.06 $\mu$m wavelength region, and high quantum efficiency, low noise detectors for the 1.5 to 2.2 $\mu$m wavelength region.
- Techniques for eye-safe measurement of the wind field and wind shear in the lower atmosphere using the edge technique with pseudo-random pulse code modulation of CW laser sources with accuracy better than 1 m/s and range resolution better than 50 m.
- Holographic optical elements (HOE) for scanning telescopes with high diffraction efficiency and narrow bandwidths. Airborne applications require up to 40 cm diameter apertures; ground-based and spaceborne applications require up to 150 cm diameter apertures. Wavelengths of special interest include 355, 523, 532, 760-770, 1046, and 1064 nm, including multiple wavelength (e.g., 523 and 1046 nm) HOEs.
- Highly efficient, compact, single-mode, pulsed, solid-state lasers tunable over 760-770nm with high frequency stability and high energy.

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## 08.10 Airborne Stratospheric Science Studies
Center: ARC

NASA requires innovations in the methods used to make measurements from airborne platforms flying in the stratosphere and to support those measurements with analyses and models. Measurements of interest include both remote measurements of the Earth's surface and remote and in situ measurements of the stratosphere from NASA's stratospheric platform aircraft (ER-2). Stratospheric composition measurements include the identify and concentration of gaseous species, as well as the number, size, shape, and composition distributions of aerosol and cloud particles. Remote measurements of the surface include the identity and condition of ecosystems on land and in water, and their relationship to other geophysical variables. These types of measurements are critical not only to NASA research objectives but may have many potential commercial applications such as water and land usage for city planning and agribusiness. Innovations needed include:

- Increased speed, sensitivity, accuracy, specificity, space-time coverage, and applicability (i.e., range of measured constituents or parameters).
- Advanced detector, source, pointing and/or tracking, and miniaturization technology as well as improved sensor survival for long periods in harsh environments.
- Self-diagnosis techniques that provide a continuous measure of data quality and instrument health. Real-time adjustments in sensor operation to compensate for instrument degradation or changes in sensed properties.
- Data-processing techniques that increase the usefulness of raw data in answering specific questions of current concern.
- Analysis and modeling the chemistry and dynamics of species measured from the ER-2 and future very-high-altitude, science-platform aircraft.

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## 08.11 Electromagnetic Measurements of Hydrological Variables in the Environment
Center: GSFC

Innovations are needed to measure electromagnetic emissions and scattering properties of hydrological aspects of the environment.

**Broadband VLF and/or ELF receivers** for sferics emitted by lightning to constitute a network to monitor continuously the global distribution of convective storms.

**L-band radiometer system** to operate on a small single-engine aircraft without pilot attention to monitor soil moisture and salinity in estuaries.

**94 GHz side-looking airborne radar** capable of determining the horizontal and vertical distribution of non-precipitating clouds to ranges of 100 km from an aircraft platform.

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## 08.12 Low-Frequency Remote Sensing Instrumentation for Subsurface Environmental Investigations

Center: SSC

Innovations are sought in low-frequency (approximately $10^3$-$10^8$ Hz), airborne, active sensor system(s) for subsurface pollution waste assessment and for soil, peatland, and shallow marine applications. Variables that need to be considered over a stratified depth profile include: salinity; soil and sediment physical properties (eg., conductivity, porosity/density, qualitative and quantitative organic/mineral composition, temperature, etc.); moisture and ice content; bathymetry and topography; and others. Frequencies selected must be capable of penetrating to approximately 10 meters depth in soil and/or rock conditions and to 30 meters depth or more (including water depth) in coastal marine environments. Centimeter to meter vertical spatial resolution and lateral resolutions of 30 meters or better are desirable. The system should also incorporate technology for good (10-to-30 meters or better) geopositioning and innovative technologies to measure variables for improved inversion data analyses.

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## 08.13 Sensor Readout Electronics

Center: JPL

Advances in sensor readout electronics are required to enable and enhance NASA missions utilizing imaging and spectroscopic detector arrays. Innovations are sought in the following areas:

- Low-noise, low-power devices and circuits for cryogenic temperatures (0.1 K to 80 K). Silicon CMOS devices and circuits operating with low noise below 8 K; devices and circuits in advanced materials such as GaAs for 0.1 K - 8 K operation; and ultra-low-noise, discrete transistors, such as Ge JFETs, at all cryogenic temperatures.

- Circuits operating with sub-electron rms read noise for detector arrays; structures for CCD output amplifiers with sub-electron read noise circuits for X-Y switched FET readout electronics; circuits suitable for large arrays that can detect and count single photo-electrons.

- Thermal compartmentalization and isolation of electronics in cryogenic dewars, such as multi-temperature, multi-stage packaging to reduce dewar thermal loads and IR photonic leaks; low-power, high-resolution (e.g. 10 mW, 50 kHz, 16 bit) A/D converters for cryogenic operation with focal planes.

- Optical transmission of data (and perhaps power) between warm electronics and cryogenic focal-planes. Such links must dissipate very low power on the focal plane.

- Readout architectures for event-driven readout of large detector arrays to enable efficient readout under sparse illumination conditions; circuit techniques and prototype readout multiplexers for such readout.

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## 08.14 Detectors and Detector Arrays

Center: GSFC

Detectors and detector arrays for space astronomy, astrophysics, geophysics, and atmospheric studies at infrared and sub-millimeter wavelengths require the following innovations:

- Composite, cryogenic, or room-temperature IR bolometers, including using diamond (optional) films coated with metal for absorbing incident radiation, with attached semiconductor or superconductor thermometers for measuring the temperature change.

- Cryogenically cooled, junction-field-effect transistors (JFETs)(2 - 4 K) with low-noise at low-audio frequencies (10 Hz) and low-power dissipation.
- Low-noise multiplexers for reduced heating of dewars at 2 K for detectors and sensors.
- Low-noise, low-power amplifiers with voltage gain and a complete line of electronic parts suitable for operation at 2 K to support cryogenic detectors.
- Micro-antenna for efficient coupling to submillimeter hetero-dyne receiver mixer diodes.
- High-efficiency, far-infrared dichroic and bandpass filters and wideband beamsplitters for Michelson interferometer.
- A low-focal-ratio, "fast", reflecting-field, optical space flight instrument system capable of focusing onto small pixels of large format infrared arrays in the 1 $\mu$m to 30 $\mu$m spectral range.
- Improved passive radiative coolers for 25-60 K operation in deep space.
- Superconducting quantum interference devices (SQUIDs) designed for low-noise readout of cryogenic detectors.
- Stable, non-mechanical, cryogenic (2 - 4 K) beam chopper or interrupter for use at far-infrared wavelengths (0.01 to 1 cm).

Detectors and detector arrays for space astronomy, astrophysics, geophysics, and atmospheric studies of x-ray, ultraviolet, and visible wavelengths requiring the following innovations:

- Three-dimensional (energy, x, y) detector arrays for UV and visible.
- Microchannel-plate, electron-intensified arrays with no ion feedback, high quantum efficiency, high resolution, low radioactivity, controlled conductivity, and high speed.
- High-quantum-efficiency, near-infrared, and UV photocathodes.
- Charge-coupled device (CCD) array improvements, including improved short wavelength response, rapid readout, and low noise.
- Array detectors for UV cameras, visible blind, high dynamic range.

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## 08.15 Infrared Detectors and Detector Arrays

Center: ARC/JPL

Innovative concepts are needed for advanced infrared detector arrays and supporting technologies to be used in astrophysics, atmospheric remote sensing, and planetary applications. Means are needed to achieve background-limited performance, simplified instrument designs, and also to support commercial sensor developments:

- Improved sensitivity of discrete IR detectors (including photon counter) and IR arrays operating at cryogenic temperatures (<12 K), with low noise, low dark current, high radiometric accuracy, and minimal radiation effects.
- Line and area-array focal planes for the 14 - 20 $\mu$m range, with temperatures between 35 and 80 K.
- Bolometric arrays operating at $He_3$ temperature for > 50 m applications.
- IR detector arrays operating with high sensitivity and high operating temperature (>200K) in the 1-3 $\mu$m range.
- Monolithic IR arrays, incorporating low-noise readout circuitry within the detector array.
- Room-temperature thermal detector arrays operating at wavelengths beyond 10 $\mu$m.
- Novel techniques in long-wavelength (>20 $\mu$m) IR filter design and manufacture.

- Long-life, low-vibration, high efficiency pulse tube and magnetic refrigerators for cooling telescopes and IR instruments to temperatures in the 2 - 80 K range.

- Methods to incorporate spectral discrimination, either by detector fabrication or on-chip optical elements, into an IR focal plane array.

- High quality, low-cost fabrication techniques for large (>1 m) optics capable of diffraction-limited performance down to 1 mm. Also, novel techniques are needed for in situ evaluation of image characteristics.

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## 08.16 Submillimeter Antennas, Radiometers, and Spectrometers

Center: JPL

Submillimeter antennas and radiometers operating in the 0.1 to 1.0 mm wavelength range for space astronomy, astrophysics, and atmospheric remote sensing require innovations in the following areas:

- Antenna systems with aperture diameters up to 4 meters and rms surface accuracies of less than 1/50 of a wavelength; multiple beams with scan angles of many beamwidths.

- Low-noise submillimeter radiometers, with $T_{REC} < 20$ hv/k, over the frequency range 350-3000 GHz, with about five-year lifetimes.

- Solid-state, phase-locked, submillimeter local oscillators up to 3000 GHz with output power greater than 100 microwatts. These local oscillators should have dc power requirements less than 20 watts, be small and light-weight, and have about five-year lifetimes.

- Microwave and millimeter-wave, integrated MMIC technology for low-power, low-weight remote sensing applications.

- Multichannel spectrometers to analyze simultaneous analysis of IF signal bandwidths up to 10 GHz with a frequency resolution of ≤1 MHz; small size, light-weight, and low dc power (< 10 mW per channel), along with high stability and lifetimes greater than five years.

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## 08.17 Instrumentation for Exobiology

Center: ARC

Exobiology seeks to understand the origin and evolution of life and life-related processes and materials throughout the universe. This requires a large, specialized cadre of analytical instruments and systems for flight experiments in low Earth orbit and on planetary missions. These instruments and systems must be highly accurate and precise while performing meaningful analyses on very small samples containing biologically important elements and their molecules. Those instruments are further required to be highly miniaturized and extremely efficient in their use of spacecraft resources requiring innovative concepts and approaches. Examples include the following:

- Miniaturized gas chromatograph subsystems including innovative detectors, columns, sampling devices, and sample treatment devices (e.g., pyrolyzers, DTA, DSC) for detection of volatile and organic compounds at parts-per-billion levels.

- Miniaturized, highly sensitive electrochemical devices to measure chemical compositions, e.g., $H_2O_2$, $NO_3$, $O_2$, $NO_x$, at parts-per-million levels.

- Miniaturized, infrared, diode laser spectrometer and subsystems, including diode lasers capable of operating at >200 K for molecular spectrometry of gases at 2-to-5 microns to measure biogenic elemental isotopes, e.g., C and N isotopes in $CO_2$ and $NO_x$, precision of 0.1 percent or better.

- Miniaturized, elemental analysis techniques (e.g., gamma ray and alpha backscatter spectrometers) with extended range and greater sensitivity for the biogenic elements (C,H,N,O,P, and S).

- Subsystems for the production, dispersion, positioning, sampling, observation, and analysis of 0.1 - 100 micron aerosol particles for low gravity experiment facilities.

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## 08.18 Filter for Solar Atmospheric Studies

Center: JPL

Narrowband, tunable filters that allow the central wavelength to be changed rapidly are used for studying solar atmospheric motions such as 5-minute oscillations. NASA seeks an improved filter with a passband as narrow as 0.125 Å that operates at wavelengths between 3900 and 7000 Å and is stable to within ±.05 Å. It should be rapidly tunable for at least ±1 Å about the central wavelength. The field of view should be at least 1 cm in diameter and capable of accepting beams with a focal ratio of up to f12. A peak transmission of at least 10 percent is required. The instrument must be readily adaptable to both ground-based and space-based observations. The filter should weigh less than 1 kg and consume 1 watt of power.

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## 08.19 Spaceborne Multispectral Imagers and Imaging Spectrometers

Center: JPL

NASA seeks specific technology advancements to enable spaceborne multispectral imagers and imaging spectrometers operating from the ultraviolet to the thermal infrared. Two areas of specific need are:

**Increased calibration accuracy**: Current radiometric calibration techniques provide only 5-to-10 percent absolute accuracy. However, absolute calibration accuracy of <1 percent radiometric, <0.1 nanometer spectral, and <1 meter geometric is desired. Specific areas of enhancement toward these goals include:

- Onboard radiometric and spectral calibration standards and calibration methodologies.
- Onboard geometric calibration technologies, including improved accuracy GPS, range sensing, and pointing knowledge.
- Low-noise, temperature-stable, silicon photo diodes with internal quantum efficiencies above 99.9 percent over the 400 - 900 nanometers spectral range.

**Innovative spectral selection techniques:**

- Tunable optical filters, including acousto-optical and liquid crystal tunable filters to operate in the ultraviolet or thermal infrared.
- Focal plane arrays integrated with spatially varying filters for both spectral selection and thermal background suppression in room temperature infrared spectrometers.
- Spatially modulated Fourier-transform spectrometers.

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## 08.20 Atmospheric Remote Sensing

Center: GSFC

The infrared (IR) region of the spectrum is a particularly useful one for spectroscopic detection and imaging of the Earth's atmosphere and planetary atmospheres, since many molecules in these atmospheres have strong absorptions at those wavelengths. Parallel development of active and passive remote sensing instruments can provide complementary measurements of important atmospheric constituents.

**Infrared acousto-optic tunable filters** (AOTF) are attractive devices for passive remote sensing. They are compact, tunable, have good resolution and produce two orthogonally polarized transmitted beams which makes them well suited for aerosol and trace gas studies. To assist in the development of instruments that incorporate AOTF's, advances are needed in the following areas:

- Transducer designs or multiple transducer configurations that enable multi-octave coverage in a single device and techniques for mounting and operating AOTFs at cryogenic temperatures.
- Reliable techniques to produce defect-free, optically clean, large aperture AOTFs that minimize contamination by scattered light, can operate beyond 5 $\mu m$, and operate at lower RF power at infrared wavelengths.

**Room-temperature tunable diode lasers (RTDL)** may soon be used for field measurements of trace gases. They are compact, power efficient, and adaptable to various instrument designs. Application of these lasers require advances in the following areas:

- RTDLs that operate between 2.0 and 3.5 $\mu m$ with stabilization techniques to ensure single-mode output.
- Sensitive detection techniques of trace gases based on RTDLs, e.g., intracavity or derivative spectroscopy.
- RTDL stabilization techniques to ensure single-mode operation.


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## 08.21 Tunable Solid-State Lasers, Detectors, and Lidar for Orbiting Platforms

Center: LaRC

Measurements to improve understanding of atmospheric chemistry and dynamics from a polar orbiting platform require development of new solid-state laser and nonlinear optical materials, laser transmitters, detectors, and lidar subsystems to meet requirements of energy-per-pulse, efficiency, lifetime, and reliability. Tunable solid-state laser technology covering the radiation spectrum from near UV through the IR is required. More specifically, innovations are sought in the following areas:

- Laser-diode arrays in the 0.67-to-0.81 $\mu m$ or the 1.4-to-2.1 $\mu m$ spectral ranges for optical pumping of solid-state materials.

- Laser diode or diode system tunable in the 0.72-to-0.73 $\mu m$, and 0.93-to-0.95 $\mu m$ ranges for stable injection seeding of long lifetime solid state lasers. Output is single frequency and >50 mW.

- Non-linear optical materials to efficiently double, triple, or quadruple the frequency of near infrared wavelengths, 0.7-to-11 $\mu m$, or to produce efficient optical parameter oscillators in the mid-IR, 2.5-to-5.5 $\mu m$.

- High-speed and/or high-quantum-efficiency detectors with low noise properties and operating in the 0.2-to-5.5 $\mu m$ region. Room temperature operation is preferred.

- Novel tunable, solid-state laser materials, especially solid-state lasers compatible with laser diode pumping. Lasing between 0.7 $\mu m$ and 1.1 $\mu m$ and 1.5-to-2.1 $\mu m$ is of particular interest.

- Continuous-wave solid-state laser devices compatible with laser diode pumping. In general, single- frequency, continuous-wave devices with a power output of 10 to 100 mW are sought. Wavelength stability and linewidth of these devices should be less than 15 MHz. A means of actively stabilizing these devices is preferred.

- Pulsed, solid-state laser devices compatible with laser diode pumping. In general, pulsed lasers operating on a single mode and producing in excess of 0.1 J/pulse at a 10 Hz pulse repetition frequency are sought. Spectral purity of the pulsed lasers should be in excess of 0.99.

- Narrow-band spectral filters having a high spectral resolution, > $10^5$, and a high peak transmission, greater than 0.5.


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## 08.22 Miniaturized Hygrometer and Datalogger
Center: JPL

**Hygrometer:** NASA is developing a compact, low-power dew-point hygrometer for use at various remote sites, possibly including the Martian atmosphere. The design utilizes a quartz crystal oscillator that is cycled through a temperature range and senses the occurrence of liquid water or frost on its surface by an abrupt change in oscillation frequency. Existing mechanical coolers are too massive and have too much thermal inertia for rapid temperature cycling. Compact, solid-state, thermo-electric (Peltier) coolers can cycle more rapidly, but the multi-stage devices needed for 50 to 100°C temperature depressions require too much power. A cooler is needed that can cycle a very small (5 cubic millimeter) thermal mass between ambient and -100°C in less than one minute. The power available is less than one Watt. The cooler must be rugged and compact (less than 10 cubic centimeters) and must have a total mass no greater than 50 grams.

**Datalogger:** The sensors used on these miniaturized meteorological stations require control and data acquisition systems that have the functionality of the state-of-the-art, low-power, intelligent meteorological dataloggers that are now used for remote, autonomous weather stations. Existing dataloggers are too large and consume too much power. Technologies are needed that reduce the size and mass of dataloggers, while being smaller than 10 cubic centimeters, having less than 30 grams mass (without batteries), providing for sensor control and calibration, and having a quiescent-mode power of less than 15 mW.

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## 08.23 Diffractive Optics Technology
Center: MSFC

Diffractive, or "binary", optics has emerged from recent advances in optical design, microlithography, reactive ion etching, ion milling, and diamond turning. It is now possible to generate precise, microscopic relief patterns on the surface of many standard optical glasses in addition to a number of unconventional optical materials, thereby allowing for new design freedom and improved fabrication techniques.

These technologies allow the development of new and unique applications, that are well suited for the space environment, that could replace conventional optical components with diffractive optics of smaller size, lower weight, lessened fabrication cost, greater ruggedness, and superior performance. In addition, ingenious diffractive optics make possible the design and manufacture of components that exhibit optical functions never before producible. Possible areas of investigation include:

- Imaging and spectroscopic systems for astronomical and earth observing missions.
- Wavefront sensing components for adaptive optical systems.
- Active optical systems for beam steering and combining.
- Unique substrate materials suited to both the space environment and fabrication requirements.

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## 08.24 Metrology for Active and Adaptive Optical Components
Center: JPL/MSFC

Active and adaptive optical components are being developed for a variety of applications. The techniques involved include high-speed, tip/tilt mirror systems, deformable mirrors, segmented mirror systems, and membrane mirrors. These types of systems can potentially be driven to closed loop frequencies in excess of 1000 hertz. The active components are then used for atmospheric turbulence correction, optical path alignment, and aberration removal. For evaluation and quantification of the various components, unique metrology must be developed in conjunction with the components themselves. These metrology systems will need to encompass the following areas.

- High-speed, interferometric figure measurements of the mirror surfaces.
- High-resolution, edge sensors for segmented systems.
- Low-cost, single-chip-based displacement sensors.
- In situ displacement measurement of actuator displacement.
- Wave front measurement systems.

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## 08.25 Innovative Optical Instrument Components and Technology

Center: JPL

Innovations in optical instrument component technology and modelling capabilities are needed to enable the development of advanced instruments for planned and future UV, visible, IR and sub-millimeter astrophysics, planetary science and extra-solar planetary detection missions. Examples include:

- Characterization and control of contamination of cryo-optics.
- Very low mass, high precision reflectors, stable with time and over temperature extremes.
- Processes for depositing and characterizing large area, damage-resistant, high reflectivity broad band coatings.
- Broad-band, high-quality polarization control elements.
- Advanced coatings for the thermal infrared, including bandpass filters and beamsplitters.
- Low-scatter optical materials, components, and finishing processes.
- Techniques and methodologies to model, characterize and suppress stray light within an instrument.
- Integrated modelling host codes for optical systems that efficiently incorporate sub-programs and include sub-program code for requirements definition and tracking, modelling of white light polarization for partially coherent fields, and radiometric modelling to 0.1% accuracy.
- Optimization algorithms.

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## 08.26 Hard X-ray Optics

Center: MSFC

Innovative optics are required to concentrate and focus hard X-rays onto space-based detector systems. The long term goal is to extend the focussing ability of practical X-ray optics up to 100 keV while maintaining or improving upon current performance in the areas of efficiency and collecting area. These optics will be used to measure cosmic x-ray emissions and for on-orbit x-ray crystallography. Important design considerations include focussing ability, field-of-view, effective collecting area, usable bandwidth, weight, size, strength, and cost. A realistic assessment of hard X-ray performance is essential. In addition to laboratory development and testing, a demonstration of actual performance would be very valuable; this could be achieved by optimizing the prototype optic for the stratospheric balloon-borne hard X-ray detector described by Ramsey et al. 1989.

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## 08.27 Technology for Precision Laser Metrology
Center: GSFC

Innovative technologies are required for performing highly accurate distance measurements on and between space platforms. Applications for this technology include astrometric interferometry, sub-mm astronomy, dilute aperture imaging, formation flying, gravity wave detection, and gravity mapping. The required accuracies are generally about 10 pm over 2 to 10 meters for the null and relative laser gauges. Absolute laser gauges with 10 nm accuracies over similar distances are also required for some applications. Inter-satellite ranging generally involves much longer baselines (~ 100 km) but the required accuracies are typically between 1 $\mu$m and 1 mm. Critical technologies supported by this research include photonics and opto-electronics, for example:

- Laser sources with long-term frequency stabilities of better than 1 part in $10^9$ over 10 hours and wavelengths between 1.2 $\mu$m and 1.6 $\mu$m. The sources should be rugged, compact, efficient, and space qualifiable.
- Optical fiducials which are stable in their optical depth at the sub-nm level against changes in environment and aging.
- Highly stable diode laser sources and acousto-optic frequency shifters integrated with isolators and fiber optic pigtails.
- Determination of absolute fringe order to better than ±0.005.
- Multi-wavelength and heterodyne interferometry for absolute length measurements.

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## 08.28 Micro-Sensors and Micro-Instruments
Center: JPL

NASA space science missions are constrained by the mass, volume, and power consumption of science instruments. Innovative proposals are solicited to develop miniature sensors and instruments for remote and in situ sensing applications and for spacecraft guidance, navigation and control. These miniature instruments will enable a new class of small spacecraft for science missions and will benefit larger space systems as well. The primary applications include planetary surface and sample return missions, earth science, space physics, and astrophysics with secondary applications in microgravity and vehicle health monitoring.

Examples of possible micro-sensors and micro-instruments include IR, visible, UV, and X-ray spectrometers and imaging systems; chemical analysis instruments such as Mossbauer, alpha particle, neutron, and mass spectrometers; and meteorological instruments, star trackers, gyroscopes, and accelerometers.

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## 08.29 Optical Technology for Planetary Science and Astrophysics
Center: GSFC/MSFC

Optical instrumentation to detect and image ultraviolet (UV), extreme ultraviolet (EUV), and x-ray radiation sources are essential in numerous NASA space missions such as AXAF-S, Far Ultraviolet Spectroscopic Explorer, and Thermosphere Ionosphere-Mesosphere-Energetics and Dynamics. Innovations are required for the following:

- Optical fabrication technology, including techniques for figure and surface roughness characterization, for x-ray and EUV missions.
- High reflectivity coatings for the UV, including large-area coating techniques.
- Fabrication and testing of optical materials and components for use in cryogenic environments.
- Diffraction grating technology for the ultraviolet.
- Test beds for testing gratings and mirrors.
- Multilayer mirror-coating technology for extreme ultraviolet wavelengths (optimized for 83.4 nm) and the definition of a technique for fabricating new technology.
- High-performance EUV filters optimized for transmission at 83.4 nm with low surface-contamination. Current techniques suffer from relatively high

surface contamination problems that degrade filter performance.

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Keski-Kuha, R.A.M., Osantowski, J.F., Toft, A.R., Partlow, W.D., "Grazing Incidence Reflectance of SiC films Produced by Plasma-Assisted Chemical Vapor Deposition," Appl. Opt., Vol. 27 (1988), 1499. A88-35023

Zukic, M., Torr, D.G., Spann, J.R., and Torr, M.R., VUV Thin Films Part II: "Vacuum Ultraviolet All-Dielectric Narrowband Filters," Appl. Opt., 29, 4293-4302, 1990. A91-11623 Combined with Part I

Zukic, M., Torr, D.G., and Torr, M.R., "High Throughput Narrowband 83.4 nm Self-Filtering Camera," Proc. SPIE 1549, 234-244, 1991. ISBN 0819406775

Hoover, R.B., Fineschi, S., Walker, A.B.C., Johnson, R.B., and Sukic, M., "Optical Configurations of H1 Lyman Alpha Coronograph/Polarimeters," Proc. SPIE 1549, 1991. ISBN 0819406775

## 08.30 Optoelectronics for Space Science and Engineering

Center: GSFC

Optoelectronic devices are useful for a number of applications in space science and engineering due to advantages in size, weight, and immunity from electrical interference. Innovative optoelectronic devices and instruments are needed in the following areas:

- Optical gyroscopes -- low-noise (noise less than 0.1 percent of measurement rate), optoelectronic inertial rotation sensors ($10^{-4}$ to $10^2$ times the earth rotation rate) using linear and nonlinear fiber optics, ring lasers, and ring resonators.
- Optoelectronic integrated circuits (OEIC) for space science (e.g. atmospheric and stellar spectroscopy applications).
- Organic and inorganic, multiple, quantum-well-structured devices for lasers, detectors, and optical modulation.
- Fiber-optic and optoelectronic sensors for spacecraft flight systems.
- 1 - 100 Mbps space qualifiable, space-radiation-immune, fiber optic data bus components and systems.
- High bandwidth (GHz), high-gain, high-sensitivity (sub-nW), and photon counting detectors at 980, 1047, and 1060 nm wavelengths.
- Lightweight 5 - 13 cm aperture gimbaled telescopes with stray light rejection for laser remote sensing and communications.

**References:**

Bergh, R.A., Lefevre, H.C., and Shaw, H.J., "An Overview of Fiber Optic Gyroscopes," Journal of Lightwave Technology, April 1984. A84-33044

Krainak, M.A., "Optoelectronics Research for Space Communications Programs at the Goddard Space Flight Center," 1991 IEEE Military Communications Conference Proceedings, Paper 47.4, 1991. A92-54824

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Photonics for Space Environments. SPIE Proceedings Vol. 1953 (1993).

## 08.31 Analytical Instrumentation for Planetary Atmospheres Research

Center: GSFC

Innovations are sought for improved operating characteristics of gas chromatograph mass spectrometer systems used for atmospheric composition measurements of planetary atmospheres. The detection and measurement of atmospheric constituents on future entry probes and flyby missions will require increased performance characteristics to meet fully the measurement goals of the experiment. Instruments sought include:

- Lightweight, miniaturized, solenoid latching valves bakeable to 300°C with a case leak rate and valve seat leak rate <$10^{-10}$ atmcc/sec. These should weigh less than 50 grams and be less than 13 mm in diameter and 4 cm in length. Valve parts exposed to the gas stream (gases will be primarily hydrogen, helium, and nitrogen) shall be free of organic and hydrocarbon contamination. The volume exposed to the gas sample shall be less than one cubic centimeter.

- Miniaturized, rugged, reliable gas chromatograph columns that provide fast elution times, high sample capacities, and reliable and repeatable operations after several years.

- Longer life, improved stability, rugged and lighter weight, high-current, pulse-counting, positive and negative secondary electron multipliers.

- Computer software to accurately simulate ion and electron trajectories in mass analyzers and focusing electrodes. Both electrostatic and magnetic fields should be represented with full, three-dimensional computation of electrostatic potentials.

**References:**

Niemann, H.B., Booth, J.R., Cooley, J.E., Hartle, R.E., Kasprzak, W.T., Spencer, N.W., Way, S.H., Hunten, D.M., and Carignan, G.R., "Pioneer Venus Orbiter Neutral Gas Mass Spectrometer Experiment," IEEE Transactions on Geoscience Electronics and Remote Sensing, GE-18, 60, 1980. A80-30840

Niemann, H.B., Harpold, D.M., Atreya, S.K., Hunten, D.M., Owen, T.C., "Galileo Probe Mass Spectrometer," accepted for publication in Space Science Review, Spring 1992. ISSN 0038-6308

## 08.32 Collimators for High-Energy Radiation

Center: GSFC

Innovations are required in the fabrication of X-ray, gamma-ray, and neutron collimators that have the precision necessary to achieve arc-second or sub-arc-second imaging in solar physics and astrophysics when used in stationary multi-trip arrays or as rotating modulation collimators. The collimators will be used to obtain images of complex sources with dimensions that could be as large as 3 to 5 arc-minutes. Collimators having the following capabilities are needed for:

- X-rays in the energy range from as low as 1 keV to as high as 100 keV with slit widths as small as 10 microns.
- X-rays and gamma-rays to energies as high as 20 MeV with slit widths as small as 20 microns.
- Gamma rays to 200 MeV and neutrons to 500 MeV with slit widths as small as 100 microns.

Fresnel-zone, plate collimators capable of ≥ 90 percent modulation of X-rays from as low as 1 keV to as high as 100 keV for use in non-rotating imaging are needed. Slit dimensions should range from 10 microns to 1 cm with an overall diameter as large as 10 cm.

**References:**

Crannel, C.J. et al., "A Balloon-Borne Payload for Imaging Hard X Rays and Gamma Rays from Solar Flares," in proc. AIAA Int. Balloon Tech. Conf. (AIAA-91-3653), Albuquerque, NM, Oct. 8-10, 1991. AIAA Paper 91-3653. A92-11002

Dennis, B.R., et al., "The Fourier Imaging X-ray Spectrometer (FIXS) for the Argentinian, Scout-launched Satellite de Aplicaciones Cientificas 1 (SAC-1)," proc. Max '91 Workshop #1 NASA/GSFC, 1988. N89-15868

Hudson, H.S., et al., "Hard X-Ray and Gamma-Ray Imaging Spectroscopy for in the Next Solar Maximum," SPIE Vol. 1344, EUV, X-Ray, and Gamma-Ray Instrumentation for Astronomy, pp. 492-503, 1990. A92-20272

Mertz, L. "Ancestry of Indirect Techniques for X-Ray Imaging," SPIE Vol. 1159, EUV, X-Ray, and Gamma Ray Instrumentation for Astronomy and Atomic Physics, pp. 14-16, 1989. A90-50253

## 08.33 High-Temperature Electronics Device Packaging

Center: HQ

Data on mission critical parameters often must be acquired in environments where the temperature exceeds the rating of conventional electronics components and packaging. These data would be concerned with conditions occurring in related engine compartments, propulsion system, skin structure during re-entry, furnace experiments, etc., and may be safety as well as operationally critical. Operation at or in excess of the operational rating of a data system markedly reduces its mean time between failures and often affects the reliability of the data. Currently such measurements are made by separating the conditioning electronics from the transducer/sensor. This approach can severely complicate and compromise measurement reliability.

Innovations are sought in devices and packaging which will provide:

- Microelectronic conditioning module for co-location with a transducer/sensor in environments up to 350°C.
- Advanced transducer/sensor for integration with a high temperature electronics module for applications at temperatures up to 350°C.
- Software for interfacing high temperature sensor with high temperature electronics module.

**References:**

Tamana, Miro, Johnson, R. Wayne, Jaeger, Richard C., and Palmour, John, "A SiC, Hybrid Operational Amplifier for 350°C Operation," Proceedings of the 42nd Electronic Components and Technology Conference, San Diego, CA, May 18-20, pp. 157-161.

## 08.34 Fiber Optics Connectors and Electro-Optic Interfaces for Extended Temperature Environments

Center: HQ

Remote sensors and fly-by-light controls would provide significant weight savings and increased reliability for space operations. Specifically, distributed power with optical invitation for actuation has been demonstrated at the laboratory level. However, cost-effective reliable hardware for flight applications has not been achieved.

New and innovative approaches are needed in the construction of electro-optical installation hardware. Specifically, innovations are sought in:

- Electro-optical connector for applications subject to temperature ranges of -60°C to 150°C and flight vibrations.
- Electro-optic to electronic couplings subject to temperature ranges of -60°C to 150°C and flight vibrations.

**References:**

NASA Publication 100063, Aero-propulsion 91; Instrumentation and Controls Research, March, 1991. N91-20086

## 08.35 Coating Materials for Electronic Packaging

Center: JPL

Advances in coating materials are sought for electronic packages in the areas of inorganic materials and materials which will provide increased radiation hardening. Size, weight savings, and improved electrical performance are key concerns. The materials and processes would be required to be compatible with standard materials used in microelectronics and produce no damaging thermal excursions. The coatings would be characterized by substrate feature conformity, uniformity, adhesion, and density. Interface interactions should be considered for typical ceramic and metallic packaging materials. Proposals are solicited in the following areas:

- Novel inorganic materials which will produce hermetic coatings for "chip-on-substrate" advanced electronic packages.
- Suitable protective coatings that will act to shield sensitive electronic components from specified radiation types, levels, durations.

## 08.36 Opto-Electronic Devices and Component Packaging

Center: JPL

Integrated photonic and optoelectronic devices operating in the spectral range of 0.5 to 5 $\mu$m are required for remote sensing, communications, and spectroscopy applications. Required innovations include:

- Single-mode tunable semiconductor lasers. Recently, the possibility of using III-V semiconductor lasers for the wavelength range from between 2 - 5 $\mu$m has been reported. InAs/GaInAs on InP substrates or GaInAsSb on GaSb substrates are of potential importance, for they offer the possibility of adjusting the band gap wavelength between 2 - 5 $\mu$m by adjusting the composition of the active layer.
- An optimized, cost-effective packaging procedure addressing the mechanical, optical, and electrical concerns for discrete devices and arrays of opto-electrical components. New assembly techniques must be developed in order to improve the time consuming and costly micro-manipulation techniques currently employed.

**References:**

Choi, H.K., and Eglash, S.J., "High Efficiency High Power GaInAsSb/AlGaAsSb Double Heterostructure Lasers Emitting at 2.3 μm", IEEE J. Quantun Electronics, Vol. QE-27, pp. 1555-1559, 1991. A91-52080

Tournie, E., Ploog,K.H., and Alibert, C., "InAs/GaInAs Quantum Wells: A New III-V System for Light Emission in the Mid-IR Wavelength Range", Appl. Phys. Letts. 61 (23), pp2808, 1992. A93-020060

## 08.37 Scanner for Geological Studies

Center: JPL

NASA utilizes an airborne, broad-band thermal infrared multispectral scanner for geological studies based on spectral signature. The Thermal Infrared Multispectral Scanner (TIMS) has six channels between 8 and 12 microns and an instantaneous field of view (IFOV) of 2.5 milliradians. The resolution is not adequate for planned studies; NASA, therefore, seeks a new high-resolution profiling scanner to fly with TIMS. This would enable the identification of the TIMS nadir pixels and provide atmosphere information for correction of TIMS data. It should have a similar IFOV and a spectral resolution of 1 wavenumber over the wavelength range 7 to 13 microns. If this would result in an unacceptable signal-to-noise ratio, a lower resolution might be acceptable. A digital visible camera aligned with the spectrometer should be included to aid in the location of the ground track.

**References:**

Kahle, A.B., et al. (1984) Active Airborne Infrared Laser System for Identification of Surface Rocks and Minerals. Geophysical Research Letters, vol. I, pp. 1149-1153. A85-14692

Hausknecht, P., and Whitbourn, L.B. (1990) Western Australian Tests of the CSIRO CO2 Laser Active Mid-Infrared Remote Sensing System. Proceedings of the 1991 TIMS Workshop, Jet Propulsion Lab. JPL Pub. 91-29.

# 09.00 Spacecraft Systems and Subsystems

## 09.01 Spacecraft Attitude Determination and Control
Center: GSFC

NASA is involved in ground-based determination of spacecraft attitude, in-flight calibration and alignment of attitude sensors, and studies of spacecraft attitude dynamics and control. Innovations are sought for new approaches in attitude determination, attitude sensor processing, and algorithms and procedures for in-flight sensor calibration and alignment for the following:

- Near-real-time multi-star identification and other methods for improved attitude sensor measurement processing.
- Generalized attitude determination techniques and filters which might be implemented in multi-mission support software.
- Tools or alternate ground operations approaches for improved flight-dynamics analysis and spacecraft support.
- Computationally efficient and innovative methods for comprehensive in-flight sensor alignment and calibration.
- Environmental models to enhance attitude sensor measurements and spacecraft dynamic simulation.
- Earth sensors that minimize power usage, cost, and weight.

Innovative concepts are sought for a simple, low cost gravity measurement sensor and on-board processor that will determine the vertical orientation of low earth orbiting spacecraft. Accuracies of less than one hundred microradians are sought for vertical offsets of less than fifty milliradians with larger errors permitted at larger offsets. The total measurement range shall be +/- one radian. A spacecraft altitude range of 300 to 3,000 kilometers is required. Measurements shall be made about once per second, near real time (with a lag of about one second).

**References:**

NASA Conference Publication 3123, Flight Mechanics/Estimation Theory Symposium - 1991. N92-14070

Sonnabend, D., and McEneaney, W.M., "Gravity Gradient Estimation" Proc. IEEE Conference on Decision and Control; Austin, TX. December 1988. A89-28571

Phenneger, M.C., Singhal, S.P., Lee, T.H., and Stengle, T.H., "Infrared Horizon Sensor Modeling for Attitude Determination and Control: Analysis and Mission Experience," NASA Technical Memorandum 86181, 1985. N85-19016

## 09.02 Guidance, Navigation, and Control of Advanced Space Transportation Systems
Center: LaRC

Future space transportation systems include expendable launch vehicles (ELVs), transatmospheric vehicles, and interplanetary spacecraft. To permit the economic viability of such systems, advanced techniques for guidance, navigation, and control (GN&C) must be developed to improve system reliability, availability, and operational capability and to reduce life-cycle costs. Innovations not based on conventional design or existing systems are solicited for:

- On-demand GN&C techniques that can be implemented on a typical flight computer.
- GN&C methods that readily adapt to environmental uncertainties encountered by a spacecraft during atmospheric flight.
- Algorithmic or computational advances that significantly improve the ability to solve complex optimization problems for spacecraft guidance.

**References:**

Cramer, E., Bradt, J., and Hardtla, J., "An Ascent Guidance Algorithm to Use On-Board LIDAR Wind Measurements," Proc. ACC, San Diego, CA, June, 1990. A90-38610

Caglayan, A., and Allen, S., "A Neural Net Approach to Space Vehicle Guidance," Proc. ACC, San Diego, CA, June, 1990. AVAIL:ESL

Mease, K., and VanBuren, M., "Aerospace Plane Guidance Using Geometric Optimal Control Theory," Proc. ACC, San Diego, CA, June, 1990. A89-24697

## 09.03 Guidance and Control for Future Spacecraft Systems
Center: JPL

High-precision guidance and control will be key elements of future space systems that must cope with onboard disturbances, system uncertainties, and configurational changes. New components, methods, and tools, whether micro or macro oriented, will need to meet greater demands for autonomy and precision while requiring less power and mass. This subtopic solicits proposals for innovative concepts to advance the technologies with the following emphases:

**Guidance and Control for Miniature Systems:** Micro-components for future miniature spacecraft missions to asteroids, comets and Pluto; micro-star and feature trackers and micro-IMUs (inertial measurement units) with masses on the order of hundreds of grams and with an order of magnitude reduction in the existing size; and micro-reaction wheels.

**Advanced Components:** Fiber-optic rotation sensors that move IRUs (inertial reference units) toward solid-state reliability; autonomous star and feature trackers that provide more powerful celestial and target tracking; and high-precision metrology systems for space-based, optical interferometric systems.

**Computational Control:** Computer-aided engineering and prototyping tools and parallel algorithms to manage complex tasks required for guidance and control. These tools should allow faster trade studies, cut analysis costs, allow quick prototyping of flight software, and provide reliable interpretation of real-time simulations.

**Advanced Concepts:** In-flight stabilization, identification, fault detection and control as well as adaptive control; control of articulating elements in linear and nonlinear regimes; and fuzzy or neural network control of systems undergoing structural and environmental changes.

**References:**


Mattler, E., et al., "In-Flight System Identification for the CRAF/Cassini Spacecraft," First IEEE Conference on Control Applications, September 13-16, 1992, Dayton, Ohio.

Staehle, R.L., et al., "Exploration of Pluto: Search for applicable Satellite Technology," Sixth annual AIAA/Utah University Conference on Small Satellites, September 21-24, 1992, Logan, Utah.

Reasenberg, R.D., et al., "Microarcsecond Optical Astrometry: An Instrument and its Astrophysical Applications," The Astronomical Journal, Vol. 96 (1988), 1731. A89-14423

Wette, M., "Casey: A Computer-Aided Engineering System," Proceedings of the 1992 IEEE Symposium on Computer-Aided Control System Design, March 17-19, 1992, Napa, CA, pg 232.

Fijany, A., "Parallel 0(log N) Algorithms for Computation of Open and Closed-Chain Multibody Dynamics," Proceedings 5th NASA Workshop on Aerospace Computational Control, August 1992, Santa Barbara, CA.


## 09.04 Spacecraft Flight Operations Automation
Center: JPL

NASA plans to reduce mission costs by developing fleets of small spacecraft that will provide more frequent access to space. Future spacecraft missions will, therefore, need to perform simultaneous flight operations while retaining or improving upon current spacecraft performance levels. Cost reduction and increased speed and accuracy of spacecraft planning, sequencing, monitoring, and analysis require automation of mission support systems so that fewer people will be able to operate an entire spacecraft system and multiple spacecraft systems. Suggested areas of innovation are:

- Rapid spacecraft uplink command sequence generation, validation, modeling, and simulation that can operate 1000 times faster than real time and accelerate the uplink preparation process by orders of magnitude.

- Human-to-computer interface technology and expert systems for automated spacecraft system-level downlink telemetry monitoring and analysis.

- Methods, hardware, and software tools for an automated and integrated framework of spacecraft subsystem performance models that can be used to generate accurate, timely performance and telemetry predictions and to facilitate spacecraft anomaly investigations.

- Methods, hardware, and software tools for a paperless operations environment that provides on-line, automatic capture, access, and update of spacecraft design and mission operations information and knowledge.

- Concepts and methods to enhance spacecraft operability and enable automated sequence generation and extensive fault-handling and self-monitoring on-board spacecraft.

- Software tools and techniques for automating information capture to support the development of an automated constraint checker for uplink sequence validation.

**References:**


Space Operations Applications and Research (SOAR) Conference Abstracts, Lyndon B. Johnson Space Center, August 1992.

Second International Symposium on Ground Data Systems for Space Mission Operations (SPACEOPS92) Proceedings, Jet Propulsion Laboratory, November 1992.


## 09.05 Tracking Systems for Spacecraft
Center: JSC

Innovations are sought in microwave, photonic, and image-based tracking systems to support autonomous rendezvous and docking, proximity operations, landing, and hazard avoidance. Areas of interest include:

**High-performance tracking systems** having greatly reduced weight, power, and cost to determine rendezvous target position, attitude, and rates (or ground-relative altitude, range and velocity for landing) while maintaining high performance and reliability.

**Passive target devices** that can be mounted on spacecraft to facilitate precision optical or image-based target tracking that is specifically near-invariant to space environmental lighting conditions (e.g. a target and sensing system which makes use of spectral cross-over in the 3 to 5 micron region).

**Sensor systems** that are light-weight and low-power, for on-orbit detection, tracking, and orbit determination of meteoroids and orbital debris in the 1 to 10 cm diameter range.


**References:**

Sensor Trade Studies by Environmental Research Institute of Michigan: Autonomous Rendezvous and Docking, June 1990; Autonomous Hazard Detection and Avoidance, July 1990; Autonomous Precision Landing, July 1990.

Space Station Tracking Study, Southwest Research Institute, January 1991.

Juday, Richard D., and Chao, Tien-Hsin, "Hybrid Vision for Automated Spacecraft Landing", Proc. SPIE 1053, 131-139 (1989).


A-90-32111

### 09.06 Microspacecraft Technology for Solar System Exploration

Center: JPL

NASA space science missions are constrained by the mass, volume, and power consumption of the spacecraft hardware. Innovative proposals are solicited to develop miniature spacecraft systems, subsystems, and/or components that will enable a new class of microspacecraft and will benefit larger space systems as well. The primary applications include flyby, rendezvous, and sample return missions to the planets, asteroids, comets, and astrophysics missions. Secondary applications include earth science missions.

Examples of microspacecraft technologies include miniature flight data systems, attitude determination and control systems, spacecraft power systems, structures with integrated thermal control and electronic packaging, chemical and/or electric propulsion systems, and deep-space telecommunication systems.

Preference will be given to concepts that can be developed quickly and tested in space within the next 3 to 5 years and have the potential for dual commercial and NASA applications.


**References:**

Microtechnologies and Space Applications, Workshop Proceedings, Jet Propulsion Laboratory, May 1992.

Sixth Annual AIAA/Utah State University Conference on Small Satellites Proceedings, Utah State University, Logan, UT, September 1992.


### 09.07 Thermal Control for Unmanned Spacecraft

Center: GSFC

Future unmanned spacecraft and space facilities will require increasingly sophisticated thermal control technology. Heat load centers will be more numerous and at widely dispersed locations, transport distances will be longer, and very tight temperature control will be required. In addition, sensors, instruments, and other electronic equipment will require cooling at different temperatures and available radiator area will be increasingly limited. Areas of innovation include the following:

**Fluid systems technology**:
- Low-temperature (60-250 K) heat pipes.
- Sensor interfaces.
- Modular, self-contained heat pumps (500-1000 W range) to allow equipment to operate at a temperature different from a central thermal bus or in a hot, thermal-sink environment.
- Long-life, no-maintenance thermal components.
- Self-diagnostic repair and correction subsystems.

**Special thermal system capabilities:**
- Utilization of low-to-medium-temperature waste heat for auxiliary cooling.
- Integration of thermal and power systems to minimize total weight.
- Innovative and or improved thermal control devices such as thermal switches, louvers, and variable temperature isothermal targets.
- Variable absorptive and emissive thermal control coatings or devices.
- Sprayable, white, electrically conductive, thermal control coatings with low outgassing characteristics.

**Thermal analysis programs**:
These should be easy to use, and able to interface with such NASA standard programs as TRASYS, SINDA85, and SSPTA. Areas of interest include the following:

- Calculation of radiant heat interchange factors including specular and diffuse reflections.
- Generation of geometric models.
- A user-friendly interface possibly making use of a graphic user interface.
- More efficient computational algorithms.
- Graphical output representation.

**References:**
Krotiuk, W.J., "Thermal Hydraulics for Space Power, Propulsion, and Thermal Management System Design," Vol. 122, Progress in Astronautics and Aeronautics, AIAA. ISSN 0079-6050

Chi, S.W., "Heat Pipe Theory and Practice," McGraw-Hill, Series in Thermal and Fluids Engineering. A77-14825

## 09.08 Conductive Thermal Control Coatings

Center: MSFC

The thermal environment of a spacecraft is dictated by the optical properties of the thermal control coatings. Current conductive thermal control coatings were developed primarily for control of spacecraft charging. However, the range of thermo-optical properties available to spacecraft designers is small, and the resistivities are still high even though sufficient for electrostatic discharge control. The use of tethered satellites and the effects due to interactions between large, high-voltage power systems and the low-earth-orbit thermal plasma highlights the need for thermal control coatings having much lower resistivities. The low voltage requirements for charging of scientific satellites in the geosynchronous and charged particle planetary environments places greater requirements on conductive thermal control coatings. The range of emissive and absorptance properties available to spacecraft designers is very restrictive. A coating whose properties can be controlled electrically would provide spacecraft designers with significantly increased flexibility in design. Innovations are needed in the following areas:

**Thermal control coatings** with electrical resistivities several orders of magnitude below those typically in use.

**Sprayable ceramic systems** capable of having their optical properties modified electrically.

**Coating systems** with the capability of selectively switching between two emissive states.

These coatings should be easily applied over large surface areas and maintain a good adhesive bond. Their electrical and thermo-optical properties degradation over mission exposure to the space environment should not alter their ability to perform their function.

**References:**
Carruth, Jr., M.R., and Vaughn, J.A., "Experimental Arching on Spacecraft," AIAA Paper No. 92-0820, January 1992. A92-29593

Shai, C.M., and Hirschfield, J., "Formulation of White Thermal Control Coating and Revised Application Procedures," NASA-TM-78086, February 1978. N79-10211

Omar, O.A., Ragaie, H.F., Fikry, W.F., "Preparation of Sprayed Tin Oxide Transparent Conducting Films and Their Structural and Electrical Properties," Journal of Materials Science: Materials in Electronics 1 (1990) 79-83.

Matthews, E.K., and Kilford, G.J., "Operating Experience with an Emissivity Measuring Laser Based Infra-Red Pyrometer," International Test and Transducer Conference Sensors and Systems Oct 24-26 1989.

## 09.09 Manned Spacecraft Internal Thermal Systems

Center: MSFC

Thermal systems for manned spacecraft require advanced thermodynamic, thermal, and fluid systems and associated computer software. This subtopic is concerned with thermal systems that are located within pressurized, manned modules. Innovations are desired in the following areas:

- Heat transport systems and concepts (including refrigeration systems with temperatures ranging from cryogenic to 0°C for zero-G operation) with acceptable safety characteristics and appropriate fluids for use in manned systems.

- Light-weight, high-capacity heat pipes for microgravity missions that can be tested on the ground at one-G.

- Two-phase evaporator and condenser components and design improvements.

- Interactive user-friendly graphical and computational techniques utilizing state-of-the-art, low-cost workstations for analysis of thermal and fluid systems.

- Design concepts utilizing thermal coatings, insulation, and heaters and for temperature sensing and data acquisition including remote measurement of low and high temperatures.

- Design concepts for long-term thermal control and storage of cryogenic or low-temperature fluids, including vapor-cooled shields, leak detection, and dewar systems for frozen sample storage and freeze drying.

**References:**
Hurst, Phyllis, "Proceedings of Annual Compressor Conference at Purdue University," Purdue University, Lafayette, IN, 317-494-0117. A86-21973

"American Society of Heating, Refrigerating, and Air-Conditioning Engineers Transactions," Atlanta, GA, (404)636-8400. A87-45460

Schlapbach, M.E., Sharp,J.B., and Szeto, M.D., "A Preliminary Analysis of the Passive Thermal Control System for Space Station Freedom," SAE 901403, July 1990. AVAIL:ESL

## 09.10 Manned Spacecraft External Thermal Control Systems

Center: JSC

Future spacecraft external thermal control systems will operate at higher loads and in more severe thermal environments than in the past, necessitating light-weight, high-efficiency, reliable thermal control systems technology. This subtopic is concerned with thermal control functions that are performed external to the pressure vessel interface and seeks innovative solutions in the following areas:

**Hardware and software methods** for measuring quality of two-phase mixtures and monitoring and controlling large two-phase fluid heat transport systems including pressure drop and flow distribution control techniques.

**Low-absorptivity radiator coatings** (alpha <0.1) with a ten-year or greater lifetime in low Earth orbit or other harsh thermal environment.

**Novel heat rejection devices** that take advantage of reduced gravity and harsh thermal environmental conditions.

**Low-temperature fluids** that do not freeze at temperatures down to 75°K or that do not have a significant volume change upon freezing or thawing.

**Light-weight, high-efficiency, heat-pump systems** to aid in habitat temperature (20-21°C) waste heat rejection to high-temperature environments.

**Light-weight radiator shade materials** with high specularity (near 100 percent) and high reflectivity (>90 percent) for space applications.

**Methods for detecting and isolating leaks** from two-phase and single-phase active thermal control systems in a vacuum, including automated software systems for locating component failures and performing isolation and recovery operations.

**Light-weight, high-heat-flux contact conductance methods** with highly reliable contact breakage and reapplication.

**Methods for enhancing thermal control system components** using electrohydrodynamic technology.

**References:**

NASA/Lyndon B. Johnson Space Center, "Human Exploration Program Requirements," Houston, Texas, August 25, 1989. AVAIL:AIAA

Smith, Robert E., West, George S., "Space and Planetary Environment Criteria Guidelines for Use in Space Vehicle Development," 1982 Revision (Vol. 1) NASA TM-82478, 1983. N83-18816

NASA/Lyndon B. Johnson Space Center, "Report of the 90-day Study on Human Exploration of the Moon and Mars," Houston, Texas, 1989. AVAIL:CASI

## 09.11 Long-Life Cryogenic Coolers for Unmanned Space Applications

Center: GSFC

NASA scientific goals require instruments with increased sensitivity. To obtain the required sensitivity, payloads will use sensors, instruments, and, in some cases, entire facilities that operate at cryogenic temperatures ranging from 120 K to 0.1 K or less. Cryogenic coolers will be required to provide these operating temperatures and those required for use of the new, high-temperature superconductors.

Future unmanned facilities will have operational lifetimes of 10 to 15 years, requiring similar total lifetimes for cryogenic coolers. This requirement can be eased if the cryogenic cooler can be easily serviced. However, on-orbit servicing is extremely expensive so both the lifetime and the reliability of the cryogenic cooler are critical performance parameters. For closed-cycle mechanical coolers, long life and reliable performance favor technologies such as non-contacting bearings and seals. For open-cycle, stored cryogen coolers, approaches are needed to greatly extend the cryogen hold-time. Areas of interest include the following:

**Mechanical cooler technology**:
- Flexure bearing technology.
- Magnetic bearing technology.
- Gas bearing technology.
- Regenerator technology, including magnetically enhanced regenerators.
- Low vibration cooler systems.
- Vibration compensation systems.
- Vibration isolation systems.
- High reliability thermal switches.
- Magnetic cooler technology.
- Interfacing mechanical coolers with sensors.

**Stored cryogen coolers**:
- Low thermal conductance structural support systems.
- Support systems with on-orbit release.
- Concepts to enhance safety.

- Concepts for stored cryogen and mechanical cooler combinations.

**References:**

Keung, C., et al., "Design and Fabrication of A Long-Life Stirling Cycle Cooler for Space Applications," Philips Laboratories, November 1990. N86-21714

Scott, Russell B., "Cryogenic Engineering. MET-CHEM Research Inc., Boulder, CO 80307. AVAIL:ESL

Fast, R.W., "Advances in Cryogenic Engineering," Plenum Press, Important Papers. A87-50751, A8343220, A85-26501, A88-53176

## 09.12 Cryogenic Fluid System Components and Instrumentation
Center: LeRC

Cryogenic liquids are required for many current and future space missions. Hydrogen, nitrogen, and oxygen (both liquid and cold gas) are of primary interest; however enhancements for other cryogenic fluids are also required. Innovative component and instrumentation concepts to improve the performance, operating efficiency, safety, and reliability of cryogenic fluid systems are solicited for both the ground and low-gravity environments. This subtopic solicits unique and innovative concepts in the cryogenic components and instrumentation areas, with an emphasis at this time for:

- Multilayer insulation concepts to improve thermal performance in low gravity (including basic design, layup techniques, and seam and penetration treatment).

- Low-gravity mass gages that do not depend upon liquid position or fluid inventory and are independent of tank geometry. Accuracy should be better than 2 percent and response time on the order of 2 seconds.

- Cryogenic temperature sensors for both gas and liquid. Sensor should be small, highly accurate and have a large range.

- Systems for ground handling of cryogenic liquids (i.e light-weight vacuum jackets, reliquifaction, etc.)

- Hardware or techniques for control of space simulation vacuum chambers including rapid pumpdown to follow launch ascent profiles and reducing back-streaming from oil diffusion pumps.

- Valving and instrumentation for flow control of high pressure (40 MPa) fluids such as $H_2$, $CH_4$, $CO_2$, and $0_2$ at flow rates on the order of 40 standard cubic meters per minute.

**References:**

Arif, H., and Kroefer, E.W., "COLD-SAT: A Technology Satellite for Cryogenic Experimentation, "NASA Technical Memorandum 102286, July 1989. N89-26036

"Zero-Gravity Quantity Gaging System, Final Report," NASA CR 185602, Ball Aerospace Systems Group, December 1989. N93-12699

Sovie, J.S., Vetrone, R.H., et al., "Test Facilities for High Power Electric Propulsion," AIAA-91-34999. N92-11136

## 09.13 Spaceflight Data Systems
Center: GSFC

Newer spacecraft concepts and design requirements are greatly increasing the complexity of flight data systems. Specifically, newer instruments are generating more science data, newer technologies require a better understanding of radiation effects, and the desire to reduce mission operations costs are dictating the development of autonomous spacecraft capable of performing onboard data reduction. Innovations are required in the following areas of technology for spaceflight data systems:

**Radiation Hard Memory:** A space-qualifiable, high-density radiation-hard memory having low weight, low power, and ruggedness is required.

**High-Speed Communication Networks:** Methods to achieve high-speed, onboard reliable communications. The trend for small spacecraft in the 1990's has been to adopt standard, serial-interface bus-oriented architectures. The bound for extensibility of this bus architecture has been the data rates achievable with current technology.

**Flight Software Architecture:** Methods for reducing the cost and risk of flight software development including software architecture, development environment, testing, and simulations.

**Mission Operations Analysis:** Methods for reducing mission operations life-cycle costs without compromising mission success. The expansion of onboard systems' capacity, flexibility, and autonomy leads to alternatives in spacecraft design that drastically impact traditional operational concepts.

**Real-Time Image Processing and Enhancement:** Software and hardware development in the areas of grey-level image enhancement, real-time edge detection for extracting both ground and atmospheric information from passive optical and radar signals, and support of on-board spacecraft activities.

**References:**
"Small Explorer Data System," Description Document, Revision 1, Available from Code 730, GSFC, November 22, 1990. A91-14985

"Second International Symposium for Space Information System," AIAA, September 17-19, 1990. AVAIL:AIAA

"Government Computing Meeting, March 14-16, Available from Colonel Will Stackhouse, Under Secretary of the Air Force, High Technology Acquisition, 1989. A88-35023

## 09.14 Spacecraft Application of Bionics and Biomimetics

Center: GSFC

Bionics seeks to derive basic engineering principles and ideas from nature, while biomimetics seeks orders of magnitude improvements in design and performance by mimicking naturally occurring processes. The development of spacecraft subsystems needs advancements in structures, materials, sensory and actuator systems, information processing, data utilization, massively distributed controls, and associated analysis capabilities. Proposed innovations must be inspired by bionics and biomimetics in areas such as:

**Actuator Systems**: Musculoskeletal systems use redundant linear actuators on light-weight, semi-rigid kinematically redundant frames to provide superior dexterity and lift capability.

**Vision Systems**: Far-field, near-field, and peripheral vision data are fused within an image processing system that responds quickly to need-based requirements.

**Proximity Detection and Control**: Proximity sensing of the local environment by a massively distributed somatic sensory system can provide feedback control information for docking, berthing, grasping, and seating.

**Data Processing**: Data from many sensory systems are fused within a data processing system that produces neuromuscular control commands "any-time". The system limits data processing to needs, it transitions between sensory systems and data fidelity needs, and it saves lessons-learned while making "any-time" decisions from incomplete knowledge.

**Adaptive Robust Control**: Complex behavior patterns are generated by cerebral and reflex control mechanisms connected by a heterogeneous neural network. The network provides robust autonomous control that quickly adapts to a dynamic environment.

**Biostructures**: Superior dexterity is achieved by an overdefined system of semi-rigid links and specialized joints. Lubrication reduces friction and wear. Joint surfaces are cushioned and designed to reduce stress induced fracturing. Fluid carrying and containment systems, valves, and pumping systems are long lasting and deformable. Bone is light, strong and tough.

**References:**
Camhi, J.M., "Neuroethology: Nerve Cells and the Natural Behavior of Animals," Sinauer Associates Inc., 1984. ISBN 0878930752

Dusenbery, D.B., "Sensory Ecology, How Organisms Acquire and Respond to Information," W.H. Freeman and Company, 1992.

Kesner R.P., and Olton, D.S., "Neurobiology of Comparative Cognition," Lawrence Erlbaum Associates, Publishers, 1990. ISBN 080501332 pbk: 0805806393

Shepherd, G.M., "Neurobiology," Oxford University Press, 1988. ISBN 0195051726

## 09.15 Artificial Intelligence for Manned Space System Applications

Center: JSC

Efficient utilization of human resources, both astronaut and ground support, for manned space missions will require intelligent systems that need minimum human attention. These systems must provide both the capability to function under a variety of conditions without human intervention and provide a means for efficient interaction with the human when needed. Innovative approaches to these two requirements should be demonstrated in a dynamic environment and modularized in a manner that allows extension of the approach to manned space missions and other applications that have similar human-resource efficiency requirements.

These approaches may include capabilities for:

- Situation assessment, response planning, and associated sensing and environment modeling.
- Natural language understanding and language planning as a modality for efficient interaction.
- Plan representation that integrates functionally with language understanding and planning to support instructability.
- Improved safety and reliability of plans and plan execution based on innovative architectures, sensing methods, and plan representation techniques.
- Support of simultaneous deliberative planning and safe, real-time action including reaction to ensure safety.

**References:**
"Cooperative Intelligent Robotics in Space III," J. Erickson, Editor, Proc. SPIE 1829, Boston, MA, 515 pages, November 1992. ISBN 9819410306

Proceedings Tenth National Conference on Artificial Intelligence, AAAI-92, San Jose, Cal., July 12-16, 1992, AAAI Press/The MIT Press, Cambridge, MA, 1992. ISBN 0-262-51063-4

IEEE Transactions on Systems, Man, and Cybernetics, Nov/Dec 1991, Vol 21, No 6, "Special Section on Distributed Artificial Intelligence." ISSN 00189472

## 09.16 Contamination Monitoring and Analysis Systems

Center: GSFC

The needs addressed by this subtopic are contamination monitoring and analytical techniques that will advance the understanding of future spacecraft contamination engineering. Innovative approaches are sought for measurement, prediction, and verification of spacecraft molecular and particulate contaminations in following areas:

**Molecular monitoring systems** to reliably measure the concentration of contaminant species, the velocity distribution, and the resulting effects such as column density, surface deposition, obscuration, and spectral background.

**Particulate monitoring techniques** to determine the particle size, density, velocity, trajectory, and the resulting effects in space environment.

**Mass transport models** to predict molecular direct transfer, backscattering, particle redistribution and trajectory, and surface contamination effects. Their implementation on minicomputer and PC-based computer systems should be improved.

**Instruments** for contamination related flight experiments with model validation.

**Computer expert systems** to train contamination engineers, to improve project management, and to perform contamination analyses.

**References:**
Triolo, J., Magg, C., and Kruger, R., "Results from A Small Box Real-Time Molecular Contamination Monitor on STS-3," Journal of Spacecraft and Rockets, Volume 21, Number 4, July-August 1984, pp. 400-404. A83-36050

Jet Propulsion Laboratory, "Contamination Analysis Program: Programmer and User Manual," August 1990.

Bird, G.A., "Breakdown of Continuum Flow in Free Jets and Rocket Plumes," Rarefield Gas Dynamics, Progress in Astronautics and Aeronautics, Vol. 74, Part II, AIAA, New York, 1981, pp. 681-694. A82-13051

## 09.17 Advanced Antenna Technology

Center: GSFC

Antenna systems are an integral part of microwave remote-sensing instruments and communication systems. Often spatial resolution and system sensitivity are limited by physical constraints and financial limitations. Increased interests in meteorological observations using millimeter-wave radars along with improved receiver performance have placed greater demands on antenna performance. For example, extremely-high polarization isolation (>28dB) is required for measuring linear depolarization ratios and differential reflectivity ratios. Clearly, improvements in antenna technology are required for advancing space-borne remote sensing instrumentation.

Innovations and improvements in antenna technologies are needed in the following areas:

**Increased isolation** between orthogonal polarizations for radar polarimetry.

**Antenna-beam scanning** without rotation of the polarization in the plane of incidence. Wide-angle scanning without lossy rotary joints in the millimeter-wave region.

**Compact packaging** suitable for operation on an aircraft and easily deployable from a spacecraft.

**References:**
Antenna Engineering Handbook, Richard Johnson & Henry Jasik, eds., 2nd edition, McGraw-Hill, New York, 1984. A85-16081

"Spaceborne Radar Would Measure Rain and Clouds," NASA Tech Brief, Vol 16, No. 4, July 1992.

## 09.18 Advanced Interface Technologies for Multimission Operations

Center: JPL

The movement away from the single mission operations toward multi-mission operations at JPL represents a major change in mission operations procedures that will require a complete overhaul of "how thing are done". As in any operational upheaval, the full impact is difficult to assess and the ripple effect is hard to predict. An increase in workload is often purported to be responsible for operator errors in critical tasks and, more generally, for reductions in operator effectiveness or productivity.

A competent environment design attempts to reduce workload by efficiently organizing the entire suite of operator tasks. Recently, system developers have begun to focus on the possibility of creating additional channels for operator-machine communication and of redistributing workload across the resulting range of control options. This is of particular interest when a vigilance task such as spacecraft monitoring must be integrated with a variety of other mission control tasks. Offloading to new channels is also of interest in the context of special environmental conditions where a mission controller is in a situation of monitoring several spacecraft. The goal is exploration and implementation of automation techniques and alternative methods of mission operations that can increase operator productivity and reduce operations cost. Some technologies of interest are:

- Voice technology for I/O
- Workload analysis techniques
- Automation techniques for task procedures
- Automated knowledge acquisition expert systems
- Information extraction and understanding from sensor data
- Man-machine interfaces capable of displaying integrated dynamic system relationships

**References:**

Waibel, A., and Lee, K., (1990) Readings in Speech Recognition. San Mateo, CA, Morgan Kaufmann Publishers. ISBN: 1558601244

Boy, G.A., and Mathe, N., (1991) Operator Assistant Systems: An Experimental Approach Using a Telerobotics Application. IJCAI Workshop on Integrated Human - Machine Intelligence in Aerospace Systems, International Journal of Intelligent Systems, Special issue on knowledge acquisition. ISSN: 0334-1860

Thimbleby, H., (1990) User interface design. New York, ACM Press. ISBN: 0201416182

## 09.19 Crew Workstation Displays and Controls
Center: JSC

The workstation design for the command and control of future manned spacecraft must incorporate state-of-the-art technologies to provide a friendly and flexible user-machine interface. To accomplish this, innovations are needed in the following areas:

- Small volume, low power, high resolution, full color, wide viewing angle, and full-motion, video-compatible, flat panel displays.

- Input devices and mechanizations that are simple and easy to use and result in high user efficiency. These devices such as a track ball, zero-G mouse, programmable switches, voice actuation, and touch screens must be compact, low power, reliable, and easy to maintain.

- Hand controller devices that could be used to support up to six degree-of-freedom, master-slave telerobotic and free flyer space operations. For telerobotic operations, force feedback shall also be considered.

- High-density local workstation data storage aids such as optical disks, disk RAMs, floppy disks, helical scan.

**References:**

Monthly Publication of the Society for Information Displays (SID). N90-25582

Proceedings of the Society for Information Displays. ISSN 0734-1768

## 09.20 Control of Flexible Space Systems
Center: LaRC

Flexible spacecraft require control systems and components that are more reliable and efficient than current systems and are robust with respect to parameter variations such as modeling errors, component failures, and disturbances. In particular, methods are needed that integrate control and structure systems design and embody advanced control system analysis and synthesis techniques, including system identification and model order reduction; fault identification, isolation, and reconfiguration; and adaptive control strategies for systems with appreciable structural dynamics. The focus should be on both robust multivariable control systems design and control devices for flexible structures and may involve ground validation of advanced system concepts and attendant breadboard hardware in Phase II or subsequent R&D activities.

**References:**

Swanson, A.D., "Proceedings of the Fourth NASA/DOD Controls-Structures Interaction Technology Conference", U.S. Air Force Report No. WL-TR-91-3013, January, 1991. N91-30148

Taylor, L.W., "Proceedings of the Fourth NASA Workshop on Computational Control of Flexible Aerospace Systems", NASA Conference Publication 10065, March, 1991.

Balakrishnan, A.V., (Editor): The Proceedings of the NASA-UCLA Workshop on Computational Techniques in Identification and Control of Flexible Flight Structures. Optimization Software, Inc. Publication Division, New York, November 2-4, 1989. ISBN 0-911575-59-6

## 10.00 Space Power

### 10.01 High-Efficiency III-V Solar Cells
Center: HQ

Lightweight, high-efficiency solar cells are necessary for future Earth-orbiting science and space exploration missions. Emphasis should be placed on innovative concepts that increase end-of-life efficiency and decrease size and weight. Considerations should also include concepts and enhancement of manufacturability. Areas of interest are:

- Improved III-V radiation resistant single and multijunction solar cells.
- Advanced III-V photovoltaic cell fabricated on alternative substrates such as silicon.

**References:**
Proceedings of the 22nd IEEE Photovoltaic Specialists Conference, Las Veges, NV, Vol. 1 & 2 (1992).

### 10.02 Static Energy Conversion Systems
Center: LeRC

Advances in static energy conversion devices are required for use in a variety of space power systems using both solar and non-solar energy sources. Examples include solar photovoltaic devices and thermophotovoltaic (TPV) conversion from an isotope heat source or a nuclear reactor. Other desired innovations include direct energy conversion from absorption of charged particles (such as alpha particles) in photovoltaic devices. For solar energy conversion, emphasis should be placed on innovative concepts that increase end-of-life efficiency and decrease the size, weight, and cost of space solar cells and arrays. Areas of interest are:

- Low bandgap solar cells for use in TPV systems.
- Radioisotope thermophotovoltaic system design and development.
- Passivation of solar cell surfaces.
- Heteroepitaxial solar cells.
- Thin films solar cells, including $CuInSe^2$, CdTe, a-Si, InP, polycrystalline Si.
- Improved contacts for III-V and II-VI solar cells.
- Concentrator cells and light-weight, high-efficiency optics.

**References:**
Flood, D.J., Thin Film, concentrator and Multijunction Space Solar Cells - Status and Potential, NASA TM 104505, 1991. N91-31218

Chubb, D.L., and Flood, D.J., High Efficiency Thermal to Electric Energy Conversion Using Selective Emitters and Spectrally Tuned Solar Cells, NASA TM 105755, 1992. N92-30426

Flood, D., and Brandhorst, H., Space Solar Cells, in Current Topics in Photovoltaics, Vol 2, Academic Press, London, 1987. ISBN 0121938603

### 10.03 Dynamic Energy Conversion
Center: LeRC

Innovative concepts are solicited in the areas of solar energy conversion, including dynamic conversion (Brayton, Stirling and Rankine) and direct thermal dynamic conversion (commercial space material processing), for use in manned and unmanned earth orbital missions. Goals include low mass, high efficiency, high reliability, and greater than ten-year operational life. Specific areas of interest are:

**Advanced solar concentrators** with emphasis on deployment schemes, accurate surfaces with high reflectivity, high concentration ratios, light-weight construction, and tolerance to spacecraft motions or jitter.

**Thermal management techniques** including advanced radiator schemes (materials, heat pipes, heat pipe materials, pumps, coolants).

**System control** with emphasis on control analysis methodologies, pointing and tracking, and techniques for determining receiver state of thermal charge.

**Solar furnace direct energy conversion** for space material manufacturing including furnace concepts, materials, and control.

**References:**
Calogeras, J.E., Dustin, M.O., and Secunde, R.R., "Solar Dynamic Power for Earth Orbital and Lunar Applications," NASA Tech. Memo. 104511. N91-27214

Wallin, W.E., and Friefeld, J.M., "Solar Dynamic Power System Definition Study," NASA CR 180877. N88-20361

Knasel, D., and Derik Ehresman, "Solar Concentrator Advanced Development Program," NASA CR 185173. N90-22834

### 10.04 Static Thermal-to-Electric Energy Conversion
Center: JPL

Reliable, long-life, high-power-density, electric power systems are needed for future spaces and planetary exploration missions. Radioisotope and reactor-based nuclear systems need higher efficiency thermal-to-electric conversion technology to reduce mass and nuclear fuel costs and enable space exploration goals to be met. Advanced thermoelectrics and thermally driven electrochemical cycles such as alkali metal thermal-to-electric conversion (AMTEC) could increase thermal-to-electric conversion system efficiencies of 3-to-5 over the state-of-the-art power systems. Advances needed for these improved technologies include:

- Improved high-temperature thermoelectric materials with increased figure of merit.
- Zero-G AMTEC (alkali-metal thermal-to-electric conversion) cell designs.
- Improved components and fabrication techniques for static conversion devices.
- Alternative high-efficiency, long-life, direct energy conversion technologies.

**References:**

C. B. Vining. "High Figure of Merit Thermoelectrics: Theoretical Considerations," Proc. 25th Intersociety Energy Conversion Engineering Conference, Am. Inst. Chem. Engineers, Vol. 2 (1990), 387-391. A91-38063

Underwood, M.L., O'Connor, D., Williams, R.M., et al. "Thermal Characterization of an AMTEC Recirculating Test Cell," Proc. 25th Intersociety Energy Conversion Engineering Conference, Am. Inst. Chem. Engineers, Vol. 2 (1990), 407-412. A91-38067

## 10.05 Miniature Power Conversion
Center: JPL

Creative concepts are desired for miniature spacecraft power conversion technology. Innovations are required for miniaturized processing of dc power into low-voltage, isolated output power forms for 1 to 30 Watts total output power. Flight instruments and spacecraft engineering subsystems require miniaturized, high-efficiency, low-noise power processing. Technology must be focussed on concepts that can survive in a radiation environment of 100 kRads. Parts, materials, and processes must support reliable performance for 5-to-20 year lifetimes. Proposals for innovations are sought in the following areas:

- Very-high-scale integration (VHSI) of spacecraft power management and distribution functions. Power integration techniques that combine switching, control, sensing, and protection circuitry within the same VHSI structure.

- Packaging techniques that provide thermal management of high-density power components via advanced materials and heat transfer methods.

- Techniques to reduce size and increase performance of capacitors so that these components can be integrated into miniaturizing packaging.

- Low profile magnetic packaging techniques and integrated-magnetics design techniques.

- Miniaturized circuit isolation techniques for highly accurate sensing methods compatible with high-frequency voltage/current control-loop performance.

- Fabrication techniques that greatly reduce output common-mode noise for sensor loads and also provide low conducted EMI on the input power bus.

**References:**

Krauthamer, S., Gangal, M., and Das, R. "State-of-Art of DC Components for Secondary Power Distribution of Space Station Freedom" IEEE Transactions on Power Electronics, Volume 6, Number 3 (July 1991). A91-49368

Krauthamer, S., Gangal, M., and Das, R. "Space Station Freedom Power Supply Commonality Via Modular Design" 25th Intersociety Energy Conversion Engineering Conference, Reno, Nevada, (August 1990. & September 1989). A91-37989

## 10.06 Aerospace Power System Automation
Center: MSFC

Innovative ideas are sought to increase power system automation for dc power systems especially for space applications. Automation here means to increase the self-sufficiency of the electrical power system. Innovations improving the intelligence and internal capabilities of the power system hardware as well as innovative approaches to power system control are being sought for electrical power systems ranging in size from small, unmanned, untended satellite-type vehicles to large, manned orbiting stations or inter-planetary vehicles. Areas of interest include:

- Power control devices and current and voltage sensors with built-in test and diagnostic capabilities.
- Software used for control and diagnosis of power system anomalies which may incorporate knowledge-based system techniques.
- Innovative hardware or software concepts useful in sensor validation to verify the quality of the data coming from the sensors.

**References:**

IECEC 1992 Proceedings "Automation Session," Document No. P259. AVAIL:SAE

IECEC 1991 Proceedings "Automation Session," Document No. ISBN 0-89448-163. AVAIL:American Nuclear Society (ANS)

## 10.07 Power Management and Distribution
Center: LeRC

Creative concepts are desired in power management and distribution (PMAD) technologies for the control of space or aeronautic power systems with increased autonomous operations. Included are hardware, software, and overall electrical system concepts that are fault- and radiation-tolerant. New concepts are sought in the following:

- Advanced materials for power electronics, devices, thermal management, and EMI shielding.
- Electronic devices, including transformers, transistors, electro-optical devices, and sensors for high-temperature, high-efficiency and/or high-frequency PMAD systems, motor drives, electrical actuation, electromechanical systems.
- Power system fault detection and isolation and system restoration, including "smart component", built-in-test, and vehicle health management concepts.
- Management, control, and autonomous operation of space or aircraft secondary electrical power systems.
- Space and planetary environmental interactions. Primary interest: environmental factors such as plasmas, atomic oxygen, particulates, and gases that affect electrical/power systems or surface materials.
- Thermal control of space power management systems. Primary interest: high-emittance radiator surfaces and advanced, light-weight heat pipes for low and high operating temperatures.

**References:**

Intersociety Energy Conversion Engineering Conference, Reno, Nevada, August 1990. A91-37926

Bercaw, R.W., "Toward an Electrical Power Utility for Space Exploration". N89-27704

Hoffman, A.C. et al., "Advanced Secondary Power System for Transport Aircraft," NASA Tech. Paper 2463, May 1985. N85-28944

## 10.08 Portable Rechargeable Energy Storage for Manned Applications

Center: JSC

Innovations in portable, rechargeable energy storage concepts yielding significant increases in the energy density over Ni-Cd and Ni-hydrogen batteries are needed to provide secondary power to such applications as cameras, tools, scientific instrumentation, life support backpacks, robotic devices, and mobile transporters. Much of this equipment is used on EVAs; consequently, it must be low in volume and weight and rechargeable. Long replacement intervals are needed to minimize the overall weight-to-orbit requirements. Safety is also of prime consideration since many of these systems are handled directly by the space flight crews and used either inside or outside habitable modules.

Of particular interest are rechargeable systems with high energy density (weight and volume) that present the least inherent hazard potential during use. The proposed concepts should provide an energy-storage building block in modular form to meet as many listed applications as possible, and be capable of hundreds of cycles as opposed to the thousands or tens of thousands required by orbiting satellite systems. Finally, the proposed concepts should present minimal constraints to future manned spacecraft personnel in their operation, during both energy utilization and energy resupply as a rechargeable energy source.

**References:**

Viswanathan, S., and Charkey, A., "Bi-Functional Oxygen Electrodes for Rechargeable Metal-Air Cells", Proceedings of 20th IECEC, August, 1985. ISBN 80898837286

Gourdine, M. C., Final Report, DARPA Contract No. DAAHO1-86-C-0975, "Thin Film Solid-State Cells with Three Inorganic Components", March, 1987. N87-25853

Venkatesan, S., Fetcenko, M., Reichman, B., and Hong, K.C., "Development of OVONIC Rechargeable Metal Hydride Batteries," Proceedings of 24th IECEC, August, 1989. A90-38236

Venkatesetty, H.V. "Electrolytes for Rechargeable Lithium Batteries," Proceedings of 24th IECEC, August, 1989. A90-38238

## 10.09 Electrochemical Storage Systems

Center: LeRC

This subtopic concerns fuel-cell-electrolyzer systems, rechargeable batteries, and other electrochemical storage systems. Component technologies for electrodes and catalysts are of interest. Proposed innovations should emphasize systems and components with increased efficiency, lifetimes, and cycling capability while reducing cost and weight and simplifying manufacture and checkout operations prior to use in space. Specific areas are:

- Advanced nickel-hydrogen systems.
- High-energy-density batteries.
- New concepts for lightweight, advanced, primary and secondary fuel cell systems.
- Improved rechargeable (but not lithium) batteries.
- Advanced energy storage systems.
- High-specific-energy or high-specific-power electrochemical systems.
- New materials for advanced rechargeable cells.

**References:**

Proceedings, 25th Intersociety Energy Conversion Engineering Conference, Reno, Nevada, August 1990. A91-37926

Proceedings, 26th Intersociety Energy Conversion Engineering Conference, Boston, MA, August 1991.
A92-50526-vol.1, A92-50604-vol.2, A92-50672-vol.3
A92-50746-vol.4, A92-50771-vol.5, A92-50811-vol.6

Warshay, M., and Prokopius, P.R., "The Fuel Cell in Space: Yesterday, Today, and Tomorrow," J. Power Sources, Vol. 29 (1990), 193-200. A90-26837

### 10.10 High-Specific-Energy Batteries for Unmanned Applications
Center: JPL

High-specific-energy rechargeable batteries are needed to provide light-weight, compact, long-cycle-life energy storage devices for future space science and planetary exploration programs. Innovations in rechargeable lithium and sodium cells are of interest in the following specific areas:

- Alternate lithium-anode materials (lithium alloys and lithium-intercalation and lithium-ion compounds).
- Organic electrolytes with wide operating window and stable towards lithium and lithium-ion electrodes.
- Lithium-polymer electrolyte systems with improved conductivity and lithium transport number.
- Overcharge and overdischarge protection methods to improve the safety of secondary lithium cells.
- High-specific-energy cathode materials with good reversibility for rechargeable lithium and sodium cells.
- Improved, solid ionic conductors for lithium or sodium ions.
- Novel design concepts for lithium or sodium cells.

**References:**

Subbarao, S., Shen, D., Deligiannis, F., et al. "Advances in Ambient Temperature Secondary Lithium Cells," J. Power Sources, Vol. 29 (1990), 579. A90-33958

DiStefano, S., Ratnakumar B.V., and Bankston, C.P., "Advanced Rechargeable Sodium Batteries with Novel Cathodes," J. Power Sources, Vol. 29 (1990), 301. A90-33936

Nagasubramanian, G., and DiStefano, S., "12-Crown-4 Ether-Assisted Enhancement of Ionic Conductivity and Interfacial Kinetics in Polyethylene Oxide Electrolytes," J. Electrochem. Soc., Vol. 137, 3830 (1990). A91-28180

## 11.00 Space Propulsion

### 11.01 Hybrid Propulsion System Technology
Center: MSFC

Innovative concepts and approaches are solicited which can assist in the design, analysis, validation testing, and production of hybrid rocket motors. Proposals should aim at mastering the basic phenomena of both forward and aft oxidizer injection, as well as research, development, production, and operations tools that will enable confident development of a hybrid flight booster. Innovations are sought in the following areas:

**Algorithms and modeling capability** required for sizing hybrid boosters, for designing components, systems and hybrid engines, and for predicting transient and steady state performance with steady and unsteady combustion and flow. Specific interests include hybrid propulsion system sizing, hybrid stage systems response to oxidizer throttling, fuel regression rate in arbitrary port cross-sections for forward oxidizer injection hybrids, combustion efficiency dependence on controlling parameters, high combustion efficiency, ignition and extinguishment control, scaling efforts, combustion, and flow stability.

**Characterization of materials** response to the hybrid environment is required to enable component and interface design over the size range up to the 2.3 megaNewton thrust scale. Specific interests include test techniques, equipment and methods, high regression rate fuels, and low regression rate insulation materials and performance prediction methods.

**Tools** to enable and simplify testing and measurement of physical and operational parameters. Specific interests in measurement include fuel regression and regression rate, insulation performance, health monitoring, anomaly testing, combustion and flow characterization.

Proposals must be hardware oriented and have near-term applicability. System studies are not acceptable. Project deliverables through Phase II should be either software to accomplish a primary objective of this subtopic or hardware and/or experimental results in support of one of those objectives.

**References:**

Jensen, G.E., Holzman, A.L., Leisch, S.O., et al., "Hybrid Propulsion Technology Program: United Technologies Chemical Systems Division-Conceptual Design Package," Hybrid Propulsion Technology Program, Marshall Space Flight Center, Vol. I (1989). N90-21793

Friedman, B., Kobayashi, A., Culver, D., et al., "Hybrid Propulsion Technology Program: Aerojet Solid Propulsion-Phase I Final

Report", Hybrid Propulsion Technology Program, Marshall Space Flight Center, Vol. I (1989).

Kuentzmann, P., Sternfeld, H. J., "What Future For Hybrid Rocket Propulsion?," Symposium Launcher Propulsion Towards the Year 2010, France, 1991, 159-168. N92-23768

### 11.02 Small Chemical Space Propulsion Systems

Center: JSC

Innovative techniques are solicited for small chemical space propulsion component and system designs that are used for auxiliary propulsion, reaction control, upper stages, and planetary descent and ascent systems. Propellants of interest include gaseous and liquid oxygen-hydrogen, oxygen-hydrocarbon, nitrogen tetroxide-hydrazine, and interhalogen-hydrazine combinations. Proposals must focus on hardware projects to demonstrate novel, low-cost, highly reliable components supporting small space propulsion systems in the following areas:

- Advanced materials for lightweight, long-life radiation and ablatively-cooled combustion chambers and nozzles.
- Techniques for injector design and fabrication, ignition systems for reaction control thrusters, and high-response, low-power thruster valve designs.
- Valves and seal concepts for high-pressure gaseous and liquid isolation, regulation, relief, quick connectors, and directional flow-control.
- Light-weight, high-pressure gaseous pressurization systems.
- Non-intrusive component and system diagnostic methods for health monitoring with emphasis on propellant leak detection and quantification.
- Zero-gravity systems for on-orbit liquid-free gas venting, gas-free liquid propellant feed and propellant mass gauging.

**References:**

Huzel, D.K., and Huang, D.H., "Design of Liquid Propellant Rocket Engines", NASA SP-125, 2d ed., 1971. N71-29405

Sutton, G.P., "Rocket Propulsion Elements", John Wiley & Sons Inc., Sixth Edition, 1992. A-92-53176

Ring, E., "Rocket Propellant and Pressurization Systems", Prentice-Hall, Inc., 1964. A-64-17659

### 11.03 On-Board Propulsion for Microsatellites

Center: LeRC

Smaller (in the 50 to 500 kg range) and more economical spacecraft and satellites to be emphasized in many future space programs will require new, highly efficient, on-board chemical rocket engines that are light-weight, compact, producible, reliable, and economical. Such propulsion systems must be able to out-perform current technology, state-of-the-art chemical propulsion systems on a mission-systems basis.

Proposals for innovative concepts that will help to achieve the desired characteristics and objectives are solicited. Areas of interest include innovative combustion and/or propellant management concepts such as high-pressure or low-pressure detonative combustion, high temperature (> 2200°C) materials used to enhance performance, and other advanced concepts suggested by offerors. Proposed projects must emphasize hardware for near-term applications; system studies are not acceptable.

**References:**

Stuart, J.R., and Gleave, J., "Key Small Satellite Subsystem Developments," AIAA Paper No. 90-3576, AIAA Space Programs and Technologies Conference, Huntsville, AL, 1990. A91-10033

Schneider, S.J., "Low Thrust Chemical Rocket Technology," NASA-TM-105927 or IAF Paper No. 92-0669, 43rd Congress of the International Astronautical Federation, Washington, DC, 1992. N93-15572

### 11.04 Launch Vehicle and Payload Dynamic Loads Estimation

Center: MSFC

The design of launch vehicle and payload components and their support structures requires the estimation of various types of dynamic loads that act upon them during service. Current methods of predicting these loads are conservative and in some instances cause undesirable payload design and weight impacts. These loads represent the component responses to environments associated with low-frequency transients, acoustics, random vibrations, and their applicable combinations. New approaches and innovative techniques to obtain improved estimates of the individual component loads and their combinations to an adequate confidence level are needed. New and novel techniques for damage modeling, measurement, and detection are also required as are innovative techniques to estimate and optimize the life of structural elements.

**References:**

Design and Verification Guidelines for Vibroacoustic and Transient Environments, NASA TM-86538, Marshall Space Flight Center, March 1986. N86-23975

Random Loads/Criteria Issues TQM Report, Marshall Space Flight Center, ED21 InterDivision Report, February 9, 1993.

Ricles, J.M., and Kosmarka, J.B., "Damage Detection in Elastic Structures Using Vibratory Residual Forces and Weighted Sensitivity," AIAA Journal, Vol. 30, No. 9, September 1992, pp.2310-2316. A92-50319

Somayajula, G., Bernard, J., "Design Optimization of Structures Subject to Static and Dynamic Constraints," Finite Element in Analysis and Design, Vol. 5, 1989, pp. 281-289. A90-17375

### 11.05 Measurement of Pump Hydrodynamic Rotor Loads and Rotordynamic Coefficients

Center: MSFC

The development of high-performance cryogenic turbopumps for liquid rocket engine propulsion is often plagued by unknown steady-state and unsteady pump hydrodynamic loads. These loads can cause excessive bearing wear, high dynamic blade loads, and rotor vibrations. Additionally, pump rotordynamic predictions are in doubt without accurately knowing the hydrodynamically induced rotordynamic coefficient associated with the pump inducer and impeller. Innovative measurement techniques are sought for measuring pump hydrodynamic rotor loads and rotordynamic coefficients. Proposals should address measurement methods and instrumentation for:

- Determining pump steady-state and dynamic blade loads.
- Determining inducer and impeller steady-state and dynamic rotor thrust and sideloads.
- Making on-rotor blade surface pressure and strain measurements.
- Extracting inducer and impeller rotordynamic coefficients.

Proposals must be hardware oriented for near-term application or use. System studies are not acceptable.

**References:**

Bolleter, U., and Wyss, A., 1985, Measurement of Hydrodynamic Interaction Matrices of Boiler Feed Pump Impellers, ASME Paper 85-DET-148.

Chamieh, D.S., Acosta, A.J., Brennen, C.E., and Caughey, T.K. 1985. Experimental Measurements of Hydrodynamic Radial Forces and Stiffness Matrices for a Centrifugal Pump-Impeller. ASME J. of Fluids Eng., Vol. 107, No. 3, pp. 307-315. A86-11970

Childs, D.W., 1989, "Fluid Structure Interaction Forces at Pump-Impeller-Shroud Surfaces for Rotordynamic Calculations," ASME Journal of Vibrations, Acoustics, Stress, and Reliability in Design, Vol. 111 pp. 216-225. A89-47712

Franz, R., and Arndt, N., 1986, Observations of Hydrodynamic Forces on Several Inducers Including the SSME LPOTP. Calif. Inst. of Tech., Div. Eng. and Appl. Sci., Report No. E249.3.

### 11.06 Computational Fluid Dynamics Methods for Rocket Propulsion System Applications

Center: MSFC

Innovative concepts are sought for improving numerical computational capabilities to predict fluid-flow phenomena in liquid and solid rocket propulsion and launch systems including multi-phase and multi-species considerations. Emphasis should be placed on methodologies and models that will enhance the efficiency and use of CFD in an applications environment that deals predominantly with incompressible or low subsonic internal flows with variable density as a result of phase changes or reaction effects. Proposals should address such issues as:

- Computational efficiency, accuracy, speed, and robustness.
- Geometric modeling, new structured and unstructured grid-generation procedures, and adaptive grid-generation methods.
- Implementation of multiblocking and zonal techniques with Navier-Stokes solvers for complex three-dimensional domain of arbitrary mappings.
- Interfacing CAD/CAM IGES files to surface and grid generators used for structured and unstructured mesh solvers for complex flow geometries.
- Automatic techniques (e.g., knowledge-based systems) for domain discretization, flow-solver operation, and flow visualization.
- Post-processing and interrogation of CFD results, e.g., solution enhancement and special purpose algorithms to delineate unique multi-phase and multi-species flow features (such as interface energy exchanges) and for efficient comparison to data.
- Flow-process modeling for turbulence, chemistry, radiation transport, multiphase, spray transport, multispecies, shock waves, and their interactions.
- Techniques which allow efficient coupling of advanced flow-process models to CFD codes in a modular fashion.

**References:**

Griffin, L.W., and Belford, K.A., "Prediction of the Aerodynamic and Thermal Environment in Turbines", ASME 90-GT-227. A91-44642

Wang, T.S., "Numerical Study of the Transient Nozzle Flow Separation of Liquid Rockets," Computational Fluid Dynamics Journal, Vol. 1, No.3, October, 1992, pp. 319-328. ISSN 0935-4964

Tucker, P.K., and Croteau-Gillespie, M., "Combustion Devices Technology Team: An Overview of STME Related Activities," 28th AIAA/SAE/ASME/ASEE/ Joint Propulsion Conference, Nashville, TN, July 6 8,1992. AIAA Paper 92-3224. A92-48825

Garcia, R., McConnaughey, P., and Eastland, A.,"Activities of the Marshall Space Flight Center Pump Stage Technology Team," 28th AIAA/SAE/ASME/ASEE/ Joint Propulsion Conference, Nashville, TN, July 6-8,1992. AIAA Paper 92-3222. A92-48823

## 11.07 Thermal Technology for Chemical Propulsion Systems

Center: MSFC

Advances in thermal technology for propulsion systems and subsystems are needed to meet the requirements of future space programs. Areas for improvement include analytical techniques, hardware component development, and instrumentation concepts for both solid and liquid propulsion systems. Specific areas in which proposals for improvements are desired include:

- Analytical techniques and advanced concepts related to the thermal design of nozzle and combustion chamber walls in liquid propulsion systems.
- Analytical techniques for the thermal design of solid rocket motor nozzles and insulation systems utilizing advanced composite materials.
- Innovative techniques in the design and installation of thermal instrumentation in rocket nozzle and throat regions.
- Analysis and design of components that generate frictional heat within high-speed cryogenic turbomachinery.
- Highly reliable (no single-point failure) heat exchanger concepts for advanced vehicle and engine systems.
- Interactive graphics thermal analysis codes and model generators, utilizing work station graphics environments and computer aided design (CAD) technology.
- Analytical techniques for simulation of manufacturing processes for liquid propulsion system components.

Proposals for system studies are not acceptable. The ultimate products of projects proceeding through Phase II must be either deliverable software to accomplish a specific purpose (such as one of those suggested above) or experimental hardware and/or test results.

**References:**

NASA-CR-120853A, "Graphite Lined Regeneratively Cooled Thrust Chamber." N72-31778

NASA TM-100343 & others, "Research and Technology 1988, Annual Report of the Marshall Space Flight Center". N89-19216

NTIS HC A99/MF E06, "Computer Codes for Thermal Analysis of a Solid Rocket Motor Nozzles." N89-21773

NTIS HC A25/MF A04, "FANTASTIC: A New Code for Thermostructural Analysis of Rocket Nozzles." X87-73862

## 11.08 High-Rate Energy Sources for Thrust Vector Control Electromechanical Actuators

Center: MSFC

Innovative concepts are solicited in the area of high-rate energy sources for electro-mechanical actuation (EMA). These sources must deliver high current pulses and maintain voltage levels over 200 volts dc (25kW - 100kW for up to several hundred milliseconds). Goals include low weights, low volume, low maintenance and increased wet life where applicable. Candidate technologies are:

- High-rate chemical battery technologies (i.e., reserve, thermal, quasibipolar, and true bipolar).
- Chemical battery-capacitor hybrids.
- High-energy "super" capacitors.
- Flywheel energy storage systems.
- Turbo-alternators.

Proposals must be hardware oriented and for relatively near-term development and application. Projects whose end products are studies are not acceptable.

**References:**

The 1991 NASA Aerospace Battery Workshop Proceedings, NASA CP-3140. N92-22740

Rose, M. Frank, "Performance Characteristics of Large Surface Area Chemical Double-Layer Capacitor", Proc. 33rd. International Power Source Symposium, J. Electrochemical Soc., Penningham, NJ, 1988. A89-44012

Keckler, C.R., et al, An Assessment of Integrated Flywheel System Technology, Conference held at Huntsville, AL, Feb. 7-9, 1984. NASA Conference Publication 2346. N85-13850

## 11.09 Launch Vehicle Rocket Engine Technology

Center: LeRC

Proposals are solicited for innovations that support launch vehicle rocket engine development and application objectives, which include improvements in performance and reliability and reduce manufacturing and operating costs. All proposals must be for specific, innovative, hardware-oriented improvements; system studies and proposals to analyze options are not acceptable. Proposals must be for improvements that can be demonstrated in the near term through SBIR projects involving experimental hardware or development of specific software, processes, or procedures.

Specific areas of interest in this subtopic include:

- Performance and reliability improvements for system components of all types.

- Hardware health management including diagnostics and prognostics to facilitate improvements in reliability.
- Components with built-in test capability.
- Techniques for data compression and transmission after fault identification.
- Techniques for combustion diagnostics of all types to ensure performance and stability characteristics.
- Techniques to reduce recurring and/or non-recurring costs of launch vehicle engines.
- Demonstrations of innovative advanced fuels for improved system performance, safety, and reliability.

**References:**

Zakrajsek, J.F., "The Development of a Post-Test Diagnostic System for Rocket Engines," 27th Joint Propulsion Conference, AIAA 91-2528, June 1991. N91-24787

Knuth, W.H., and Crawford, R.A., "Oxygen-Rich Combustion Process Applications and Benefits," AIAA 91-2042, June 1991. A91-44102

Palaszewski, B., and Rapp, D., "Design Issues for Propulsion Systems Using Metallized Propellants," AIAA/NASS/OAI Conference on Advanced SEI Technologies, AIAA 91-2484, September 1991. N91-29220

# 12.00 Human Habitability and Biology in Space

## 12.01 Medical Sciences for Manned Space Programs

Center: JSC

Human presence in space requires understanding of the effect of microgravity and other components of the space environment on the physiological systems of the body and on the psychology of the crew. Countermeasures must be developed to oppose deleterious changes in these systems either in space or on return to earth. Health care and medical intervention must be provided over extended duration missions. Proposals should address new and innovative concepts and technologies that could be key to forwarding these objectives. Areas of interest are:

- Improved, non-invasive methods to evaluate the function of the cardiovascular, neurological, bone, muscle, and pulmonary systems.

- Methods and equipment to maintain and assess levels of aerobic and anaerobic physical capability.

- Approaches to sustain, maximize, assess, and model individual and team performance.

- Identification of countermeasures against deleterious changes in body systems in flight or on return to the ground. Changes include space adaptation syndrome including space motion sickness, in-flight loss of muscle and bone mass, postflight orthostatic intolerance, and postflight reduction in neuromuscular coordination.

- Approaches to prevent or minimize decompression sickness associated with in-flight pressure changes and assess the effect of microgravity on gas bubble formation or incidence after in-flight decompression

- Approaches to achieve health care and intervention within the operational constraints of space flight. These approaches include extended shelf-life pharmaceuticals, diagnostic methods and procedures, medical imaging systems, noninvasive medical monitoring, dental care and surgery, and blood replacement technology.

**References:**

Nicogossian, A., Huntoon, C.L., Pool, S.L., et al., "Space Physiology and Medicine, 2nd ed.," Philadelphia, PA 1989. A90-16625

NASA-CP-10048, Workshop Report: Pharmacokinetics and Pharmacodynamics in Space, August, 1988.



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10th Frontier Symposium: Clinical Pharmacology in Space, in The Journal of Clinical Pharmacology, Vol. 31, No. 10, October 1991. A93-17527

## 12.02 Biomedical and Environmental Health Sciences for Manned Space Programs

Center: JSC

Manned space missions generate requirements for a variety of environmental and biomedical activities to protect crew health and to counter the effects of space on human physiology. These activities require innovative, space-flight-compatible approaches in clinical laboratory operations, environmental health monitoring, and maintenance. Innovations are needed for the following:

- In-flight monitoring techniques including fiber optics (IR, UV, visual sensors) and bio-sensors for chemical, microbial, and physical quality of recycled water and atmosphere, spacesuit atmosphere, food, and surfaces. Of particular interest is the detection, measurement, removal, and health-effects assessment of organic contaminants.
- Methods of assessing the overall acceptability of the environment for human habitation and methods of assessing associated risks.
- Methods for maintaining microbial quality of the atmosphere, water, and surfaces during extended missions and means of assessing their effectiveness.
- Techniques for monitoring non-ionizing and ionizing radiation and for determining organ doses. Quantitative measurement of the cytogenic and carcinogenic effect of protons and heavy ions, especially at low doses. Methods for measuring cellular and tissue levels mechanisms and effectiveness of radio-protectants.
- In-flight procedures and techniques for assessing the human metabolism of protein, carbohydrate, lipids, vitamins, and minerals.
- In-flight specimen collection and analysis to evaluate physiological, metabolic and pharmacological responses of astronauts. Non-invasive methods to measure crew performance and related influential factors.
- Novel software methods for documentation, storage, retrieval, analysis and diagnosis of crew health and environmental quality information.

**References:**

NASA JSC 24439, SSF Toxicology and Environmental Monitoring, Nov 1989. AVAIL:SSC

NASA JSC 32024, Conference Report: Space Station Water Quality, March 1987. AVAIL:JSC

NASA CP10048, Workshop Report: Pharmacokinetics and Pharmacodynamics in Space, Aug 1988.

NASA Technical Memorandum 4270: Radiation Health Research, 1986-1990, avail. NTIS, March 1991. N91-21704

## 12.03 Human Monitoring Technologies for Assessing Effectiveness of Adaptive Physiologic Mechanisms

Center: ARC

Long-term exposure to microgravity requires new technology and instrumentation to develop effective adaptive mechanisms for maintaining performance. Innovative concepts and instruments are solicited for monitoring use in ground-based studies. Also, innovations are needed to maintain safe and productive human performance. Technologies that minimize time, power usage, and hardware mass and volume while maximizing accuracy, reproducibility, simplicity, and automation are encouraged.

- Instrumentation to be used in ground-based studies for reliable and accurate noninvasive monitoring of human physiological function such as the cardiovascular, musculoskeletal, neurologic, gastrointestinal, pulmonary, immunohematological, and hematological systems.
- Methods to monitor physical activity and loads placed on different segments of the human body.
- Exercise equipment to load the musculoskeletal and cardiovascular systems with the capability to monitor, record and provide feedback about performance.
- Noninvasive instruments to provide quantitative data to establish the effectiveness of an exercise regimen in ground-based research.
- Innovative means to apply artificial gravity and to reduce deleterious effects associated with short-arm centrifuges.

**References:**

Hubbard, G.S., Hargens, A.R., "Sustaining Humans in Space," Mechanical Engineering, Vol. 111 (1989), 40-44. A89-54375

Aratow, A., Hargens, A.R., Meyer, J.U., et al., "Postural Responses of Head and Foot Cutaneous Microvascular Flow and Their Sensitivity to Bed Rest," Aviation Space Environmental Medicine, Vol. 62:246-251, 1991. A91-27970

Cowings, P.S., "Autogenic-Feedback Training: A Treatment for Motion and Space Sickness," Motion and Space Sickness, CRC Press, (1988), Chapter 71. N89-15517

Cohen, M.M., "Physiological and Behavioral Adaptations to Microgravity," Invited paper presented to the American Association of Aeronautics and Astronautics Symposium, Space Station in the 21st Century, Reno, NV, AIAA Paper Number:AIAA-86-2336, Sept 1986.

## 12.04 Medical Sensors and Instrumentation for Manned Space Programs

Center: JSC

Manned operations in space place special requirements on medical sensors and instruments. As launch costs are extremely sensitive to mass and volume, sensors and instruments must be small and light with a premium on multi-functional aspects. Low power consumption is a major consideration, as are design enhancements to improve operation in zero-G. As the efficient utilization of time is extremely important to manned space flight, innovative instrument setup, intuitive human interfaces, ease of usage, improved astronaut (patient) comfort, non-invasive sensors, and easy to read information displays are all important human factors considerations.

Innovations are needed in but are not limited to:

- Advanced blood analysis instrumentation.
- Optical sensors for blood and urine analysis.
- NMR sensors for blood and urine analysis.
- Smart sensors (On-sensor data processing and sensor reconfiguration).
- Ultrasonic Doppler systems for blood flow.
- Virtual medical instrumentation.
- Automated biomedical analysis.
- Micro-gravity blood and respiratory gas analyzers.
- Micro-gravity refrigeration systems for the storage of biological samples and incorporating refrigerants acceptable for use in a sealed environment.

**References:**

Taylor, Gerald, "The Space Station Freedom Biomedical Monitoring and Countermeasures (BMAC) Project - Inflight Equipment Derivation", February, 1990.

Sanson, W., et al., "A Smart Sensor for Biomedical Applications", Proceedings of the Annual International Conference of the IEEE Engineering in Medicine and Biology Society, Seattle, WA., 11:1088-1089, Nov. 1989. ISSN 0739-5175

Bryzek, J., et al., "Silicon Sensors and Microstructures in the Health Care Industry", Proceedings of Sensor Expo International, Cleveland, OH, pp. 303A1-303A10, Sept. 1989.

Black, W.C., "Biomagnetism--Magnetic Source Imaging", Medical Electronics, Oct. 1991, pp. 61-67. ISSN 0149-9734

## 12.05 Water Purification Utilizing Microorganisms

Center: MSFC

Innovative methodologies incorporating microorganisms as purifiers and recyclers of materials and nutrients are sought. The characteristics of such methodologies must include biological self-sustainability, reliability, stability, and compactness. Innovations in the following areas are sought:

- "Living filters" or filters colonized by selected microorganisms capable of breaking down and/or utilizing toxins or other undesirable materials.
- Microorganisms to break down ligno-cellulose, and methods for linking (e.g., via trophic relationship) such organisms biologically and ecologically with other organisms, including humans, in a closed system.

**References:**

Drake, G.L., et al., (1966) Study of Life Support Systems for Space Missions Exceeding One Year in Duration. IN: The Closed Life Support System. NASA SP-134 (1967). N67-34584

Giesy, Jr., John P., ed., (1980 Microcosms in Ecological Research. Symposium Proceedings, November, 1978. Technical Information Center, U.S> Dept. of Energy CONF-781101. N83-73659

Obenhuber, D.C., (1988) Carbon Recycling in Materially Closed Ecological Life Support Systems. BioSystems 21: 165-173. A89-37673

Wright, D., C.E> Folsome, and D.C. Obenhuber (1985) Competition and Efficiency in Closed Freshwater Algal Systems: Tests of Ecosystem Principles. BioSystems 17: 233-239. ISSN 0303-2647

## 12.06 Regenerative Life Support: Air, Water, and Waste Management

Center: ARC/JSC/MSFC

Closure of regenerative life support systems is essential for the success of future human planetary exploration. The requirements include micro- and partial-gravity operation, high reliability, elimination of expendables, and low system weight and power. Innovative, efficient, practical concepts are desired in all areas of regenerative physical, chemical, and biological processes, associated hardware, sensors, and instrumentation for basic life support system functions including air revitalization, water reclamation, and waste management. All proposals must lead to specific Phase II experimental development projects that could be integrated into practical life support systems.



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**Air Revitalization:**

- $O_2$, $CO_2$, and $H_2O$ vapor concentration, separation, and control techniques including regenerative physical, chemical, and biological approaches.
- Gas-phase separation of $CO_2$ from a mixture primarily of $N_2$, $O_2$, and water vapor to maintain concentrations of $CO_2$ below 0.4 percent by volume.
- Highly efficient gas-separation of $N_2$ and $O_2$ from $CO_2$ to reduce concentrations of $N_2$ and $O_2$ to less than 0.2 percent by volume.
- Trace contaminant removal.
- Regenerative sorbent beds.
- Improved oxidation techniques (physical chemical/biological).

**Water Reclamation:**

- Efficient, direct treatment of waste water (e.g., urine, wash water, and condensates) without requiring expendables to produce potable and hygiene water; includes stabilization of waste water and purge gases prior to storage, processing, or overboard venting.
- Stabilization and processing of waste water effluent gases for recovery without the use of expendables.
- Potability maintenance techniques.
- Recovery of water from waste water concentrates.
- In situ cleaning and sterilization of potable water systems.

**Waste Management:**

- Stabilization of wastes (metabolic and inedible biomass) and recovery of useful products (e.g., $N_2$, $H_2$, $CO_2$) from organic waste materials.
- Microbial techniques for waste treatment in micro- or partial-gravity.

**References:**

Doll, Susan C., and Case, Carl M., "Life Support Function and Technology Analysis for Future Missions," Boeing Aerospace & Electronics, 20th Intersociety Conference, Williamsburg, Virginia, July 1990. A90-49291

Wydeven, T., "A Survey of Some Regenerative Physico-Chemical Life Support Technology," NASA Technical Memorandum 101004, November 1988. N89-12207

McDonnell Douglas Space Systems Company, Space Station ECLSS "Evolution Study," Huntsville, AL, June 1989. AVAIL:CASI

NASA Workshop on Resource Recovery from Waste Generated in Lunar/Mars Ecological Life Support Systems (CELSS), NASA/Johnson Space Center, JSC 25736.

Morrison, Dennis R., "Suspension Cell Culture in Microgravity and Development of a Space Bioreactor," in Proceedings of the Space Bioreactor Workshop, NASA Conference Publication #2485, NTIS, Springfield, VA., 1987, pp. 1-18.

Todd, P., et al., "Cell Bioprocessing in Space: Applications of Analytical Cytology," The Physiologist Vol. 31 (No. 1, Suppl.): pp. S-52 - S-55, 1988.

NASA Technical Memorandum 4191: Microgravity Sciences and Applications Program Tasks, 1989, avail. NTIS, May 1990.

## 12.07 Regenerative Life Support: Sensors and Controls

Center: JPL/JSC

Regenerative life-support systems for extraterrestrial human missions require integrated operation of a variety of physical-chemical and biological processes. Nonlinear responses to input changes must be monitored and controlled in real-time to return the system as quickly as possible to an optimal state. The task is complicated by degradation mechanisms. Innovations needed include:

**Micro-miniaturized sensors** capable of real-time multiple measurement functions and self-calibration are required. There is an urgent need to integrate specific measurements of chemical and biological species concentrations with temperature, pressure, and mass flow rate on micro-miniaturized sensors. Development of in-situ sensors of this type are required for gas and aqueous media.

**Pre-training artificial neural net controllers** that are designed to provide rapid real-time control using mathematical models of degradation. This pre-training is required because it is not feasible to train these neural nets for future degradation of process equipment. Simulation of artificial neural net performance will be acceptable if extant neural net chips will not be adequate.

**References:**

SAE Technical Paper Series, reprint 891341, 19th International Conference on Environmental Systems, July 24-26, 1989.

SAE Technical Paper Series, reprints 911322, 911323, 911324, 911325 and 911326, 21st International Conference on Environmental Systems, July 15-18, 1991.

SAE Technical Paper Series, reprints 921119, 921120, and 921172, 22nd International Conference on Environmental Systems, July 13-16, 1992.

## 12.08 Regenerative Production of Food

Center: ARC/JSC/KSC

NASA's future long-duration missions mandate extensive regeneration of life support consumables and utilization of local planetary resources. Regenerable life support systems with higher plants, microorganisms, and physicochemical processes for recycling air and water, processing wastes, and producing food are required. Components must minimize mass, volume, power, and thermal requirements, as well as crew requirements.

**Sensing and monitoring devices for:**
- $O_2$, $CO_2$, humidity, dissolved and volatile organics, soil moisture content, and microbial flora.
- Volatile and soluble organics in air, transpired water, nutrient solutions, and soils.
- Control of pH, water levels, flow, salinity, turbidity, electrical conductivity, and nutrient composition within hydroponic solutions, and soils.
- Plant photosynthetic and respiratory gas exchange.
- Automated biological tissue sampling.
- Non-invasive monitoring of plant health.

**Plant Growth:**
- Alternate plant lighting methods.
- Utilization of waste heat and transpired water.
- Processing wastes and inedible biomass.
- Automated robotic computer-vision systems for crop propagation, planting, cultivation, harvesting, and food processing.
- Techniques for growing or propagating plants such as tissue culture; techniques for improving plant materials.

**Monitoring and control:**
- Integrated monitoring and control.

**Atmospheric Gas Storage:**
- Oxygen gas storage methods.

**References:**

Dreschel, T.W., and Sager, J.C., "Control of Water and Nutrients Using a Porous Tube: A Method for Growing Plants in Space," HortScience, Vol. 24 (1989), 944-947. A97-16126

MacElroy, R.D., and Greenwalt, S., "Controlled Ecological Life Support Systems," NASA TM 102277, March 1990. AVAIL:CASI

Ming, D.W., and Henninger, D.L., (editors), "Lunar Base Agriculture: Soils for Plant Growth," American Society of Agronomy, Inc., Crop Science Society of America Inc., Soils Science Society of America, Inc. Madison, WI. 1989. A91-14726

Prince, R.P., Knott, W.M., and Sager, J.C., et al., "Design and Performance of the KSC Biomass Production Chamber," Transactions of the Society of Automotive Engineers, Vol. 96 (1987), 6.472-6.476. A88-21100

## 12.09 Human Factors For Space Crews
Center: JSC

Innovative devices and techniques are required to enhance crew operations under all space flight conditions and to facilitate the design of crew accommodations and human-to-systems interfaces for the zero-G environment.

- Anthropometric and biomechanics inflight measuring systems which can be used to determine acute and long-term performance responses in the zero-G environment.

- Computer modeling tool kits supporting dynamic computer models of humans and environments for visualizing and simulating lighting, sound, motion, strength, tasks, and behavior to be used for designing and planning activities and tools.

- Techniques for providing data and models of human perceptual and cognitive processes for the development of cooperative intelligent systems and optimization of human cognitive workload for the control of space systems.

- Enhanced human interfaces with telerobotic and automated systems.

- Efficient light-weight lighting sources for general and task illumination that utilize minimum power and are safe for in-flight use.

- Layout, arrangement, and decor of spacecraft interiors to promote effective use of zero-G in carrying out living and working tasks.

- Means to temporarily stow loose equipment with some type of zero-G retention system that is non-flammable, does not contaminate the atmosphere, is reusable and cleanable.

- Provide a data base or procedure for methodologies, techniques, and evaluation criteria for evaluating IVA/EVA crew performance and productivity.

- Lightweight means to control the spacecraft acoustic environment.

**References:**

Woolford, B., Pandya, A., and Maida, J., "Development of Biomechanical Models for Human Factors Evaluations," Proceedings of Space Operations, Applications, and Research (SOAR) Symposium, Albuquerque, N.M, June 1990. N91-20713

Koros, A.S., Wheelwright, C.D., and Adam, S.C., "Effects of Noise on Crew Members During Spacelab Life Sciences - 1." 123rd Meeting of the Acoustical Society of America, Salt Lake City, Utah, 1991.

Goldsberry, B., Lippert, B., McKee, S., et al., "Using Computer Graphics to Design Space Station Freedom Viewing," Proceedings of the IAF Congress of Malaga, ACTA Astronautica, Vol. 22. A90-13306

## 12.10 Man-Systems Integration in Space Systems

Center: MSFC

Man-systems integration (MSI) employs the systems approach to achieve the integration of the human operator(s) (on-orbit crew and ground-based personnel) and space systems. It is accomplished by the systematic application of MSI principles, practices, and techniques to the design of equipment, systems, architectural spaces, operations, and training. An emerging technology being utilized as an MSI analytical tool is immersive, fully interactive, computer-generated simulations (aka virtual reality). Innovative proposals should be directed towards enhancing and/or enabling the application of this simulation technology in MSI in space systems. Specific areas of emphasis are:

**Human factors analyses:** viewing (including diopter adjustment), reach and dynamic work envelope (including proximity, contact, and force feedback), audible acoustic environmental noise (including dynamic adjustment for noise source amplitude and directionality), and illumination (including point sources and glare).

**Improved system capabilities:** increased graphical object detail and realism, enhanced object behavior and dynamic attributes and interactions (including coordinate system reassignment and kinetic energy transfer), improved image resolution, innovative body tracking and anthropomorphic interaction devices.

**Anthropometric computer model** that puppets the user's behavior including: selectable link lengths and statues with proportionate body dimensions, the ability to add body coverings or specialized suits, and selectable strength capabilities that dynamically vary with mechanical advantages and postural changes.

**Transportable systems for training** that can operate, stand-alone and/or be fully interactive with remote training simulators.

**Utilization** of existing interactive graphics design system (IGDS) and engineering modeling system (EMS) design files.

**References:**

Hale, J.P., (1992), "Marshall Space Flight Center's Virtual Reality Applications Program." In WESCON/92 Conference Record (pp.382-386) Ventura, CA: Western Periodicals Company.

Handbook of Human Factors. John Wiley & Sons, Inc. (1987). ISBN 0471880159

NASA STD 3000, Man-System Integration Standards. N90-71357

## 12.11 On-Board Systems and Support for Space Crews

Center: JSC

Innovative concepts in crew accommodations, equipment, and procedures are required to support complex future manned space missions. Areas of interest include safety, comfort, performance, and productivity of crew members.

**Personal hygiene systems** and procedures in a zero or partial gravity environment. The objective is to enhance crew living accommodations while minimizing required resources. Examples of interest include: total body cleaning methods and hardware, hair grooming methods and hardware, and personal cleansing agents compatible with both open and closed loop life support systems.

**Decontamination methods** for crew members exposed to hazardous substances.

**Housekeeping** solutions to problems encountered in both zero and partial gravity environments including: crew habitat cleaning, trash management systems and techniques, apparel cleaning, noise abatement and control, particulate reduction and control, and cleansing agents compatible with both open and closed loop life support systems.

**Food management systems** and procedures in both zero and partial gravity environments, such as extending shelf life including packaging and preservation technologies, improvements in acceptability and palatability, and improvements in food waste management systems.

**Inventory management** with emphasis on consumables and crew equipment tracking systems.

**References:**

Bourland, C.T., Fohey, M.F., Kloeris, V.L., et al., "Designing a Food System for Space Station Freedom," Food Technology, Vol. 43 (1989), 76-81. AVAIL:ESL

Klicka, M.V. and Smith, M.C., "Food for U.S. Manned Space Flight," Tech Report TR-82/019. U.S. Army Natick R&D Laboratories 01760, Natick, MA 1982. N83-11745

Johnston, Richard S., and Dietlein, Lawrence F., "Biomedical Results of Skylab," NASA SP-377, 1977. N77-33780

JSC 26823, Approaches to the Design of a Housekeeping System in Microgravity. AVAIL:JSC

## 12.12 Extra-Vehicular Activity

Center: ARC/JSC

Extensive new requirements for extra-vehicular activities to support complex future human space missions will require innovative approaches to maximize crew productivity and capability to perform useful work tasks while reducing ground launch-to-space resupply weight and volume penalties for EVA support systems expendables. EVA system design approaches that minimize crew member fatigue and unproductive EVA overhead penalties such as time spent servicing and checkout and that have low energy and power consumption characteristics are needed. Areas of interest include:

- Low venting or non-venting regenerable individual life support subsystem(s) concepts for crew member cooling, heat rejection, removal of crew member expired water vapor and carbon dioxide, and electrical energy sources that minimize crew member EVA system volume and weight.

- Long life chemical oxygen storage systems for an emergency breathing oxygen supply.

- Light weight and high strength composite materials and related manufacturing processes to reduce crew member EVA system volume and mass.

- Materials for space suit thermal control having variable insulation and infra-red emissivity properties that are capable of either rejecting or preserving heat (when facing the sun or when facing deep space).

- Space-suit gloves made with size reproducible manufacturing processes and techniques that provide highly dexterous hand, fingers, and thumb mobility and fingers and thumb tactile sensitivity.

- Hardware and software for objective evaluation of pressure suit glove performance including mobility characteristics and crew member hand fatigue.

- Techniques for analyzing laminate and stitched fabric pressure structures, pressure suit fabric integrity, structural joints and attachment methods.

**References:**

Kosmo, J.J., et al., "Development of Higher Operating Pressure Extravehicular Space Suit Glove Assemblies," SAE 881102. A89-27894

Chodack, J., et al., "Space Suit Glove Thermal Micrometeoroid Garment Protection Versus Human Factors Design Parameters," SAE 911383. A92-31308

Wilson, J., and Lawson, M., "Investigation Into Venting and Non-venting Technologies for Space Station Freedom Extravehicular Activity Life Support System," SAE 901319. A91-50546

Rosso, M.J., et al., "A Fuel Cell Energy Storage System for Space Station Extravehicular Activity", SAE 881105 and SAE 891582.

## 12.13 On-Orbit Environmental Noise Control Measures

Center: MSFC

Long-term exposure to excessive noise will affect crew performance and productivity. In the past, astronauts have complained of excessive internal noise during on-orbit operations. In this application, weight, size and volume is limited. New concepts and innovations are being solicited to develop new noise control measures and techniques to reduce the source of the noise, increase the attenuation during propagation of the noise and/or to increase the absorption of the noise during reflections. Improved methods and techniques for predicting the acoustic environment in the habitat are also being sought. Specific areas in which innovations are requested include:

- Aerodynamically designed low-noise-source fans.
- Improved low-noise design of pumps, compressors, and water separators used in environmental control and life support systems.
- Active noise cancellation devices and techniques.
- Improved enclosures, silencers, absorbers and tuned resonators designs.
- High acoustically absorbent materials suitable for on-orbit applications.
- Light-weight, high-transmission-loss materials for use in racks and enclosures.
- Improved, efficient analytical modeling techniques for predicting the internal sound (audible) field in a highly three-dimensional enclosure.

**References:**

NASA STD 3000, Man-System Integration Standards. N90-71357-vol.1, N90-71356-vol.2

Hirschorn, Martin, "Compendium of Noise Control Engineering - Part I," Sound and Vibration, July 1987. ISSN 0038-1810

Hirschorn, Martin, "Compendium of Noise Control Engineering - Part I," Sound and Vibration, Vol. II, February 1988. ISSN 0038-1810

## 12.14 Optical Imaging Systems and High-Resolution Electronic Still Photography

Center: JSC

Extended-duration spaceflight and exploration missions will require innovative techniques to solve unique optical and photography problems, particularly for storage and near-real-time, high-resolution image return.

Innovations are desired in both optical systems and components and mega pixel high-resolution electronic still-photography systems and components. Emphasis in the proposal evaluation will focus on a concept's potential to provide greater utility, efficiency, resolution, image compression, and value to the flight crew on long duration missions. Technical thrusts and improvements for electronic still photography involve the following:

- Electronic still-camera systems with operation and performance similar to a 35mm film camera.
- Devices for small, removable, high-density, digital image storage media.
- High-resolution image sensors for electronic photography systems.
- Manipulation and processing of megapixel image data.
- Image data compression schemes adaptable to electronic still-photography systems.
- Low-noise, high-efficiency battery-power conversion.
- Methods for archiving uplink, downlink, and display of images and data.
- Error detection and error correction, versatile transmission systems, and image data compression during transmission.
- Color splitting in a small system utilizing a minimum of three sensors.
- Anti-reflective coatings for image sensors and optical components.
- Image depth perspective and dimension measurement.
- Obtaining ultra-thin optical low pass filters for single color sensors.

**References:**

Proceedings from the SPIE/SPSE Electronic Imaging Science and Technology Conference, February 24-March 1, 1991, San Jose, CA. ISBN 0818620617

Research and Technology Annual Report, NASA Johnson Space Center, 1989, Subtitle: Electronic Still Camera Project. N90-21721

Research and Technology Annual Report, NASA Johnson Space Center, 1990, Subtitle: Electronic Still Camera Project. AVAIL:JSC

## 12.15 Bio-Degradation of Inedible Plant Materials to Produce Additional Edible Food Products

Center: SSC

This subtopic addresses ecological waste management for the disposal of inedible cellulytic and lignolytic waste matter. For this requirement an innovative alternative to landfill disposal is solicited. In natural ecosystems, inedible plant material (leaves, twigs, logs, etc.) are naturally decomposed through the use of cellulytic and lignolytic decomposer organisms.

The purpose of this request for innovations to decompose certain urban and industrial waste products through the use of cellulytic and lignolytic edible fungi. Innovative approaches required are: a) decomposition of solid vegetable matter via the use of edible cellulytic fungi producing another edible food product - up to 30 percent weight of the substrate, b) a decomposed substrate that can be used commercially as a humus or if disposed using landfills resulting in a greatly reduced volume of the initial waste product.

The Phase I deliverable will consist of a final report and a functional prototype of a waste processing system of sufficient technical depth to proceed to Phase II. Ideally, Phase II would investigate multiple species and contrast their effectiveness for various waste handling methodologies using the waste matter as the substrate.

**References:**

Stametz, P., and Chilton, J.S., 1983, The Mushroom Cultivator. 415p. Agarikon Press, Olympia, WA.

Chang, S.T., and Hayes, W.A., 1978, The Biology and Cultivation of Edible Mushrooms. Academic Press, New York. ISBN 084936758X

Gramss, G., 1979, Some Differences In Response to Competitive Micro-organisms Deciding on Growth Success and Yield of Wood-Destroying Edible Fungi. Mushroom Science X:265-285. Proceedings 10th International Cong. Cult of Ed. Fungi., Bordeaux, France.

Wright, S.H., and W.A. Hayes, 1979, Nutrition and Fruitbody Formation of Lepista nuda (Bull. ex. Fries) Cooke. Mushroom Science X:873-884. Proceedings of 10th International Cong. Cult. of Ed. Fungi, Bordeaux, France.

# 13.00 Quality Assurance, Safety, and Check-Out for Ground and Space Operations

## 13.01 Shuttle Operations Weather Forecasting, Modeling, and Display

Center: KSC

**Lightning and Electrification Processes Modeling:** Direct and induced effects of lightning to systems are experienced frequently at KSC. Triggering of lightning by vehicles during ascent and descent is a particular hazard. New models relating to this hazard are needed in the following areas:

- Cloud electrification processes.
- Direct and induced lightning effects on systems and structures.
- Thunderstorm forecasting and lightning prediction.

**Meteorological Data Product and Graphic Merger for Display:** The weather forecaster today is faced with a multitude of data that must be assimilated in the process of analysis, synthesis, and prediction. Innovations are required in merging data products and/or graphics from multiple independent systems and to synthesize new products for a single display system that permits efficient assimilation of the information by a user.

**References:**

Terrestrial Environment (Climatic) Criteria Guidelines for Use in Aerospace Vehicle Development, Robert M. Turner and C. Kelly Hill, compilers. 1982, NASA TM-82473 (supersedes TM-78118). NASA Scientific and Technical Information Office.

National Fire Protection Association, National Fire Protection Code, NFPA 78, Lightning Protection Code.

## 13.02 Remote and In Situ Sensors of Weather Hazards

Center: KSC

To ensure the safety of space vehicles during launches and landing, stringent safety criteria to avoid weather hazards have been defined. Conditions that must be avoided include electric fields aloft that trigger lightning; fog and low stratus clouds that obscure landmarks and the landing strip from above; and winds exceeding specified velocities in the surface boundary layer (surface to 30 m).

Innovations in ground-mounted sensing and monitoring devices are needed for:

- Determination of the three-dimensional structure of the electric field in clouds not producing lightning.

- Detection and estimation of depth of fog and low stratus cloud formation. A low-maintenance, self-powered sensor robust enough for deployment in remote uninhabited swampy areas and capable of telemetering appropriate data for this purpose is needed.

- Measurement of wind speed and direction from the surface to 30 m using a surface-mounted sensor that would eliminate the need for a tower, which alters the wind being measured, increases maintenance costs, and constitutes an aviation hazard. It would also allow placement of sensors along the flight path at the end of the runway.

- Determination of the distribution of soil moisture to improve performance of existing numerical prediction models. A low-maintenance, self-powered sensor to measure moisture in the top 10 to 30 cm of soil robust enough for deployment in remote broad areas and capable of telemetering data to central collection site is needed.

High-quality data from these sensors is essential. To achieve this, innovative automated real-time methodologies to provide quality control of data from an array of surface sensors and/or vertical profiles from a single site are desired.

**References:**

Turner, R.E., and Hill, C.K., compilers, "Terrestrial Environment (Climatic) Criteria Guidelines for Use In Aerospace Vehicle Development," 1982. NASA-TM-82473. N82-28317

## 13.03 Verification of Models for Hazardous Materials Transport

Center: KSC

Diffusion and transport of toxic fluids and particulates in the atmosphere from an inadvertent release during hazardous ground or launch operations is a major concern at Kennedy Space Center (KSC). A KSC safety review panel recommended adoption of a number of numerical prediction models. High-resolution assessments of model predictions must be made to ensure compliance with regulations. Innovative concepts are solicited for accurate but cost-effective sensor systems and measuring techniques for field verification of the accuracy of numerical model predictions and for field assessment of hazard during emergencies.

**References:**
Hanna, S.R., Messier, T., and Schulman, L.L., Hazardous Response Modeling Uncertainty (A Quantitative Method). USAF Engineering and Services Laboratory Technical Report ESL-TR-88-16 (AD-A203 886; available Defense Technical Information Center, Alexandria, VA), 1988.

Proceedings, International Conference and Workshop on Modeling and Mitigating the Consequences of Accidental Releases of Hazardous Materials, New Orleans, LA (American Institute of Chemical Engineers, New York), 1991.

"On-Site Meteorological Program Guidance for Regulatory Modeling Applications," EPA-450/4-87-013, U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, NC, June 1987. N88-14498 AVAIL:NTIS:PB87-227542/XAB

Hosker, Jr., R.P., Rao, K.S., Eckman, R.M., McQueen, J.T., and Start, G.E., An Assessment of the Dispersion Models in the MARSS System Used at the Kennedy Center. ATDL Contribution No. 92/18, Air Resources Laboratory, National Oceanic and Atmospheric Administration, Silver Spring, MD 20910-3233, 1992.

## 13.04 Nondestructive Inspection of Ceramic Components

Center: MSFC

Ceramics are being proposed for use in bearings for rocket engines that provide better wear characteristics and performance. A concern with these ceramics is the lack of an inspection system that can readily verify their integrity. An innovative system is desired for quantitative nondestructive inspection of these parts in the green and fixed condition. The goal is to determine their integrity and to screen for flaws. Cracks, voids, and porosity-- both internal and surface--can degrade the performance of these parts leading to premature failure and formation of debris. Because existing inspection techniques are inadequate, proposals for new methods or a combination of methods are solicited for performing a quantitative inspection without adversely affecting the ceramic parts. The method should provide for rapid inspection with provision for storing all relevant data. It should be capable of easy interpretation, with a display that marks a flaw and its dimensions. The method of inspection should not damage the ceramics or contaminate them such that extensive cleaning is required. Since the parts may be exposed to liquid oxygen, contamination is a great concern.

**References:**
Sutton, P.D., Hillier, L.R., Sawicka, B.D., "Computed Tomography and Ultrasonic Testing of Urania Fuel Pellets," Review of Progress in QNDE, Vol. 8B, 1988. ISSN 0743-0760

## 13.05 Advanced Strain Measurement Technology

Center: SSC

Rocket motor test capabilities would be enhanced by the use of a new type of strain measurement technology. Innovations are sought in two areas:

- A method of applying strain sensors to a test article in sheets such that the entire area for which stress information is desired is covered.
- Local processing capability so that remote data acquisition is not burdened by whatever processing the sensor requires.

The Phase I effort would develop an approach and preliminary design for an integrated sensor/processor system. The Phase II effort would consist of the construction and test of an actual prototype system that could be tested or evaluated on a rocket test motor.

**References:**
Aronson, M.H., and Nelson, R.C., "Strain Gage Instrumentation," Instruments Publishing Co., 1960.

Perry, C.C., and Lissner, H.R., "The Strain Gage Primer," McGraw Hill, 1962.

Pople, J., "BSSM Strain Measurement Reference Book," BSSM, 1979. ISBN 0950635103

Dally, James W., "Experimental Stress Analysis," McGraw Hill, 1991. ISBN 0070152187

## 13.06 Hydrogen Fire Detection

Center: SSC

Multiple area coverage sensors are needed to continuously monitor hydrogen facilities for fires. Innovative technology is required to detect hydrogen fires without causing alarms due to background sources such as welding, lightning, or greater than 400 liters-per-minute hydrogen flare stacks. Since hydrogen fires are not visible to the human eye during daylight conditions, the system should visualize or indicate the size of the fire to the operator. The sensor package should have the capability to be networked with other sensors and utilize imaging technology to recognize a fire, provide an alarm, and then display the image associated with the alarming sensor. Although high-cost systems based on ultra-violet or infra-red optical systems have been demonstrated, it is felt that a fusion of new technologies in the areas of image processing, optics, and radiation detectors could lead to lower-cost, continuous monitoring systems.

**References:**

Cholin, John, Optical Fire Detection, Chemical Engineering Progress, New York, American Institute of Chemical Engineers, July, 1989. ISSN 0360-7275

Kharbanda, Hardip S., Remote Video Enhances Protection, Consulting-Specifying Engineer, April, 1991, p.56. ISSN 0897-5046

Schwartz, D.B., Machine Vision Fire Detection, The Military Engineer, No. 551, August 1992, p.59. ISSN 0026-3982

Tomlin, Alison S., Pilling, Michael J., Turanyi, Tamas,. Merkin, John H., and Brindley, John, Mechanism Reduction for the Oscillatory Oxidation of Hydrogen: Sensitivity and Quasi-Steady-State Analyses Combustion and Flame, Vol. 91, No. 2, Nov. 1, 1992, p107+. A93-13319

## 13.07 Static Charge Detection Device

Center: KSC

Materials used in hazardous or explosive environments are required to pass a test used to predict the ability of materials to generate and hold potentially hazardous static charges. The KSC triboelectric test is described in the report cited below, which describes a test apparatus used to rub the surface of a test material for 10 seconds with a force of 1.4 kgf before it is placed in front of a special detector that measures surface charge. In order for the material to be considered acceptable, it must show less than 350 volts charge after a five second decay period.

One critical piece of equipment used in this device is the static detecting head. This unit is no longer being manufactured or sold. Innovations leading to an improved and less-expensive charge measurement and processing system utilized in performing the referenced test are solicited.

**References:**

Standard Test Method for Evaluating Triboelectric Charge Generation and Decay" Report No. MMA-1985-79, Rev 2, dated 7/15/88, NASA, Kennedy Space Center, Florida.

## 13.08 Toxic Propellant Detection

Center: JSC

Testing of space flight and ground equipment requires state-of-the-art safety devices to support operations. A technique to detect airborne, parts-per-billion concentrations of hydrazine, monomethyl hydrazine and unsymmetrical dimethyl hydrazine, and nitrogen tetroxide is desired. Significant reductions in the threshold limit value (.01 PPM for the hydrazines) are scheduled to be implemented in 1993 by the American Conference of Governmental and Industrial Hygienists. Current technology provides techniques to measure concentrations in the parts per million range. The new technique should feature a portable device that will provide accurate and rapid measurements to facilitate field operations.

**References:**

American Conference of Governmental Industrial Hygienists, Documentation of Threshold Limit Values and Biological Exposure Indices, latest edition, Cincinnati, Ohio. ISBN 0936712961

Eiceman, G.A., Young, R.C., Travis, J.C., et al., "Ion Mobility Spectrometry in Monitoring Hydrazines and Hazardous Organic Compounds in Air and Water," 1990 JANNAF Safety & Environmental Protection Subcommittee Meeting, Livermore, CA. X91-72095

Grate, J.W., Rose-Pehrsson, S.L., and Barger, W.R., "Hydrazine Detection Using Chemiresistors," 1988 JANNAF Safety & Environmental Protection Subcommittee Meeting, CPIA Publication 485, Monterrey, CA. X89-72537

Smith, P.T., Paige, K.M., and Hawkins, C.M., "Hydrazines Detection Using Photoionization," 1987 JANNAF Safety & Environmental Protection Subcommittee Meeting, CPIA Publication 466, Cleveland, OH. X88-71431

## 13.09 Low-Impact and No-Impact Pressure Relief Devices

Center: SSC

Safety relief valves currently used in high-pressure systems can close with high speed and introduce impact loads on the valve and induce pressure pulses or spikes in the fluid system. Designs and prototype development of safety relief valves for aerospace cryogenic fluids (primarily oxygen and hydrogen) in liquid, gaseous, or mixed phase states that close with a modulating pressure control characteristic are desired. Design relief pressures should cover the range of 1 to 70 MPa. The first prototype should cover a set range of 20 to 44 MPa.

**References:**

Ulanski, Wayne "Valve and Actuator Technology", McGraw-Hill, Inc., 1991. ISBN 007194777

Zappe, R. W., "Valve Selection Handbook", Third Edition, Gulf Publishing Co., 1991. ISBN 0442318707

Merrick, Ronald C., "Valve Selection and Specification Guide", Van Nostrand Reinhold, 1991. ISBN 0442318707

## 13.10 High-Pressure, Cryogenic Liquid Level Measurement

Center: SSC

Innovative approaches are necessary to develop systems to accurately determine liquid level of cryogenic liquids such as hydrogen, oxygen and nitrogen in large, high-pressure vessels (greater than 2000 liters and 6 MPa to 45 MPa). Any measurement technique must consider heat loss and material compatibility with liquid hydrogen and oxygen and unique states of the cryogenic fluids that can occur at these pressures. Equipment used in the system should be available as much as possible as off-the-shelf components. Accuracy of one to two percent of volume is required. The instrumentation should work under static and dynamic conditions and have a response time of less than 50 milliseconds. This subtopic solicits proposals for innovations to make these measurements possible. Areas of interest include:

**Intrusive Measurement:** Intrusive measurement techniques must make innovative use of small pressure measurement ports or another access method. Innovations in sensors that operate at high pressures are necessary for intrusive measurement techniques.

**Non-Intrusive Measurement:** Innovations in measurement techniques or sensors may allow determination of liquid level without tank access. A strong focus should be made to utilize vibration, optical and/or sonic methods of measurement.

**References:**

Kato, Kiyonori, "Liquid Helium Level Meter by Audio-Sound Detection," Review of Scientific Instrumentation, Vol. 60, No. 7, 1989, 1343-1345. ISSN 0034-6748

Liu, F.F., and Chow, S.W.H., "Differential Dielectric-to-Density Measurement for Cryogenic Fluids," Review of Scientific Instrumentation, Vol. 58, No. 10, 1987, 1917-1925. ISSN 0034-6748

Woodhouse, Christopher E., Kashani, Ali, and Lukemire, Alan T., "Superfluid Helium Tanker Instrumentation." IEEE Transactions on Instrumentation and Measurement, Vol. 39, No. 1, February 1990, 274-278. ISSN 0018-9456

Zuckerwar, Allan J., Mazel, David S., and Hodges, Donald Y., "Ultrasonic Level Sensor for Liquids under High Pressure," Review of Scientific Instrumentation, Vol. 57, No. 9, 1986, 2318-2320. A87-11223

## 13.11 Non-Intrusive Pressure and Temperature Measurements

Center: SSC

Aerospace facilities require accurate measurement of pressure and temperature for the liquid and gas piping systems supporting the development and testing of rocket engines. Incorporation and maintenance (primarily calibration and cleaning) of sensors in facility systems is expensive. Penetrations into piping systems, are also a potential source of leaks. New, non-intrusive techniques for pressure and temperature measurements in closed piping systems are needed for facility piping systems. Built-in sensor calibration and diagnostics are also required of new sensors. Sensors for pressures up to 70 MPa and temperatures ranging from cryogenic to 1700°C are needed.

**References:**

Figliola, Richard S., and Beasley, Donald E., "Theory and Design for Mechanical Measurements," John Wiley & Sons, 1991. A91-27330

Tse, Francis S., "Measurements and Instrumentation in Engineering: Principles and Basic Laboratory Experiments," M. Dekker, 1989. ISBN 0824780248

Benedict, Robert P., "Fundamentals of Temperature, Pressure and Flow Measurements, Third Edition," John Wiley & Sons, 1984. ISBN 0471893838

## 13.12 Micromechanical Device Technology

Center: KSC

Advanced electronic chip manufacturing technology has provided a new capability to fabricate micromechanical devices and simple systems. Innovations which exploit the use of micromechanical device technology for aerospace-related systems are sought. These innovations should provide improved performance, efficiency, reliability and/or maintainability over current aerospace technologies. Examples of the types of devices sought include:

**Miniature Load Cell:** Small or miniature load cell, 0-100,000 Newton range, accurate to ±100 Newton based on using micromechanical device technology to sense the changes. Desired maximum volume of 130 cc, self-contained except for power input and data readout ports.

**Oxygen Deficiency Meter:** A miniature (credit-card size) oxygen deficiency meter to be carried or worn by personnel. The unit is to be self-powered and self-contained. Output desired is an automatic audible and visual alarm if oxygen is out of prescribed limits.

**X, Y, Z Axis Accelerometer with Solid State Data Storage:** A tri-axial accelerometer that will store the data on an internal, solid-state, data storage system and that contains an internal power supply. Minimum size is highly desirable (about 6 cubic inches or less) as is the ability to record approximately 10 data value readings per axis per second for at least 24 hours. The ability to download data to external, portable standard PC-compatible computers is required. Sensitivity desired is ±0.1 G each axis, with a maximum of 50 G over bandwidth of 100 Hz.

**Facility Gas Systems Purity Measurement:** A unit to measure the particulate contamination of compressed gas facility systems such as breathing air, $GN_2$, $GH_2$, and He is desired. The device should be installed in the pneumatic system, allow in-place calibration, and measure quantity and size of particulate using a portable, external readout and data storage unit when required.

**References:**

O'Connor, Leo, 'MEMS: Micromechanical Systems', Mechanical Engineering Feb 1992, pages 40-47.

Robinson, Gail, 'Micromechanics Drives New Gears Of Innovation', Design News Feb 10, 1992, pages 23-24.

Rosen, Jerome, 'Micromachining in The Micro Domain', Mechanical Engineering March 1989 pages 40-46.

ME Staff 'A Revolution In The Making', Mechanical Engineering March 1989 pages 47-48.

### 13.13 Computer-Assisted Generation of Job Standards for Low-Frequency Industrial Applications

Center: KSC

The human engineering involved in determining how long a job or task should take is usually a time-consuming and labor-intensive process. Most computer-based tools for generating job standards are developed at the micro-motion level for highly repetitive tasks. In Space Shuttle ground processing and depot maintenance of large aircraft, a growing need exists for applying the same work measurement principles to tasks that are repetitive but less frequently performed and of longer durations. The environment in which these tasks are performed is "risky" with respect to hazardous operations as well as cost and schedule measures.

Innovative methods are solicited to develop a computer-assisted tool for generation of job standards to be used in space shuttle ground processing. The methodology should:

- Perform work measurement at several levels of motion granularity(micro to macro levels)
- Allow for unique working conditions in NASA and other industrial environments
- Have a generic structure to allow basic job standards to be built on for various shuttle elements, several processing facilities, and future launch systems.

**References:**

Konz, Stephen, Work Design: Industrial Ergonomics, Second Edition, John Wiley and Sons, New York, 1983

Polk, Edward J., Methods Analysis and Work Measurement, McGraw-Hill Book Company, 1984.

Zandin, Kjell B., MOSTR Work Measurement Systems, Second Edition, Marcel Dekker, Inc., New York, 1990.

### 13.14 Hierarchical Network Simulation and Modeling to Support Resource Allocation in Risky Environments

Center: KSC

Operational analysis of the tasks associated with Space Shuttle ground-processing requires consideration of a large, complex project management network and allocation of a wide variety of resources. Enhancements to the current work analysis procedures should enable consideration of probabilistic descriptions of activity durations and resource allocation in the stochastic scheduling environment. Simulation capabilities are desirable to enable rapid decision making with respect to resource allocation in an environment subject to technical, cost, and schedule risks.

Comprehensive measurement of the performance on a particular activity requires simultaneous consideration of multiple criteria. Modeling procedures should also provide the capability for formulation of a multiple criteria performance measurement system. The analysis of ground processing data is performed at several levels. Integrated hierarchical networking procedures are required to enable comprehensive analysis.

Innovative network modeling and analysis procedures are solicited to enable hierarchical network simulation analysis, rapid resource allocation in risky environments, and comprehensive multiple criteria performance measurement.

**References:**

Bowers, M.R., and Jarvis, J.P., 'A Hierarchical Production Planning and Scheduling Model', Decision Sciences, Vol. 23 1992, pages 144-158.

Norman, V.B., 'Future Directions in Manufacturing Simulation', Industrial Engineering, Vol. 24, No. 7, July, 1992, pages 36-37.

Pritsker, A.B., 'Simulation: The Premier Technique of Industrial Engineering', Industrial Engineering, Vol. 24, No. 7, July, 1992, pages 25-28.

Sink, D. Scott, Productivity Management; Planning, Measurement, Evaluation, Control, and Improvement, John Wiley and Sons, New York, 1985.

## 14.00 Satellite and Space Systems Communications

### 14.01 Communications and RF Systems for Space Vehicles
Center: JSC

Multiple, simultaneous, efficient links will be required for low-rate and high-rate communications and RF system components for space exploration systems, space transportation systems, future manned spacecraft, satellites, and extravehicular astronauts. Areas for innovation include:

- Multiple beam antennas with near-hemispherical coverage at Ku, Ka, W-band, and optical frequencies for supporting up to six simultaneous multiple access users. Techniques for minimizing grating lobes, achieving high-efficiency front-end (power amplifier and low-noise amplifier) performance, minimizing electronic components by using monolithic microwave integrated circuits (MMIC) technology, and utilizing conformal array antennas for near-range (less than 1 km).

- High-gain (greater than 50 dB), narrow scan (± 3° elevation, ± 1° azimuth) phased array antenna concepts for short-time duration (less than 10 seconds) tracking of 1 cm and larger orbital debris particles out to 300km range. Techniques for using battery-stored energy for supplying short-term power to such a radar system. Adaptive (as a function of range) signal processing schemes for minimizing the radiated power requirements. Photonics to distribute phase information across the large antenna for beam steering.

- Ultra-small, active, integrated microwave sensors to allow embedded measurement and relay of spacecraft parameters to centralized instrumentation data terminals.

- Innovative schemes for highly efficient microwave beam power transfer. Required support technology includes beam steering accuracy, minimizing grating lobes, photonics for phase reference distribution, minimizing EMI noise outside the transmission frequency band, and high conversion efficiencies for dc to RF and RF to dc.

- Light-weight, low-power spaceflight encoders to allow highly bandwidth-efficient space-to-ground transmission of HDTV.

- Highly automated communications control, monitoring, and test systems to allow ultra-rapid, fault detection, isolation, and recovery.

**References:**

IEEE International Communications Conference - ICC '91, Space Station Communications, Denver, Colorado, June 1991. ISBN 0780300068

IEEE Global Telecommunications Conference - GLOBECOM '90, Space Communications Systems. San Diego, California, December 1990. A91-53161

SPIE (International Society for Optical Engineering) Conference, Application of Ka-band MMIC Technology for an Orbiter/ACTS Communications Experiment, Orlando, Florida, April 1990.

### 14.02 Optical Communications for Deep Space
Center: JPL

Future deep-space-exploration spacecraft will use optical frequencies to communicate back to near-Earth orbit or directly to the ground. Innovative concepts are needed for:

**Lasers that have high-power conversion efficiency** (approximately 10 percent), produce single and stable far-field beam profiles, and can be modulated easily using a pulse position modulation format with high peak pulse energies (0.1-1.0 mJ).

**A micro-chip diode-pumped solid-state laser** with greater than 200 mW of 1064 nm average power at Q-switched repetition frequency of 2 kHz. Wall-plug efficiencies of greater than 10 percent are desirable.

**A flight qualifiable dual-axis scanning mirror** with angular range of greater than ±3 degrees, pointing resolution of better than 0.1 micro-rad, and bandwidth of greater than 1 kHz. The scanning mirror (excluding the driver) should be compact (about a 2.5 cm cube) and lightweight (about 0.2 kg).

**A 10-cm diameter diffraction-limited optical telescope** with greater than 70 dB of off-axis light rejection and a total mass of less than 0.5 kg. The telescope should be able to remain intact and aligned after being subjected to a 60g acceleration.

**An APD-type detector** for 1064-nm wavelength with greater than 80 percent quantum efficiency and gain over 100.

**High-gain, focal-plane, detector arrays** with electronically-controlled cursor readout. A kiloHertz readout rate (with single or multiple pixel), a gain of million, and a responsiveness better than an S-20 photocathode are desired.

**Design approaches and concept verifications** for coherent optical transponder functions.

**Optical reception telescopes** with large aperture (greater than 5 meters in diameter), inexpensive, non-diffraction-limited primaries for use on the ground or in space. Reception wavelengths for these "photon buckets" are in the 0.5-to-1.2 micron region. Concepts and design verifications are sought for using such telescopes at small angles off the solar limb (ie., at small Sun-Earth-spacecraft angles).

**References:**

Lesh, J.R., "Optical Communications Systems and Technology for Deep-Space Exploration," Proceedings of Optical Space Communications Conference at the Second International Congress on Optical Systems and Engineering (ECO2), Paris, SPIE, Vol. 1131 (April 1989), 236-239. A90-38025

Lesh, J.R., "Deep Space Optical Communications--A Program Update," SPIE OE Lasers 90, L.A., CA, paper 1218-43 (Jan. 1990), 530-540. A91-22820

## 14.03 Optical Communications for Data Relay Satellite Systems

Center: GSFC

NASA's next generation of small, scientific and data relay satellites will be equipped with free space laser communications terminals and fiber-optic networks. These systems require advances in the state of the art of optoelectronics technology that will afford the user lighter weight, lower cost packages capable of being implemented in the space environment. The emphasis over the next 5 years will be in low-to-moderate data rates; specifically, 1 to 20 Mbps rates for telemetry and control fiber optic spacecraft buses, 20 to 3000 Mbps sensor fiber data buses, and 1 to 5 Mbps intersatellite links. Innovations are needed in the following areas:

**Lasers for free space communications transmitters,** that are small, high-efficiency, diffraction-limited near-infrared sources capable of modulation at the rates mentioned above.

**Binary optics** for near-IR source-beam shaping and delivery systems for increased robustness due to lower parts count and improved alignment sensitivity.

**Optical receivers** to detect and demodulate the incoming data stream. These detector-preamplifier modules should provide high sensitivity and be immune to the effects of ionizing and proton radiation effects in low earth orbit.

**Fiber optic network** concepts, devices, and proof-of-principle, prototypes that address the multiple-access local area network problem on spacecraft both for the low-end T&C bus and the high capacity, wideband sensor data bus architectures. Technologies addressed here will be somewhat dependent on the topologies, protocols, etc. that are selected for the space environment; however component technologies needing development include radiation-tolerant transmitters and receivers, source-to-fiber coupling, tunable semiconductor lasers, star couplers, connectors, modulators, and fiber media.

**Innovative optoelectronics implementations** for integrating key transmitter and receiver electro-optic hardware assemblies, providing increased robustness to the launch environment, ease and cost-effectiveness of integration, and reduced weight and power burden to the spacecraft.

**References:**

Ondrus, P., "Small Satellite Tracking and Data Relay Capabilities and Future Mission Requirements," NASA Tech Note 510-T&DR-1, Sept. 1992, Code 510.1, NASA/Goddard Space Flight Center, Greenbelt, Maryland, 20771. A91-22816

Seery, B.D., "The Goddard Optical Communications Program," Free-Space Laser Communication Technologies II, SPIE, Vol. 1218 (Jan. 1990), 13-26. A91-22778

Davidson, F.M., Sun X., and Krainak, M.A., "Bandwidth Requirements for Direct Detection Optical Communication Receivers with PPM Signaling," Free-Space Laser Communication Technologies III, SPIE, Vol. 1417 (Jan. 1991). AVAIL:AIAA

Flanegan, M., and LaBel, K., "Small Explorer Data System MIL-STD-1773 Fiber Optic Bus," June 1992, NASA Technical Paper 3227. N92-26667

## 14.04 RF Components for Satellite Communications Systems

Center: LeRC

Innovations are being sought for devices, components, and subsystems for new applications and increased capabilities for a broad spectrum of civil-space communications applications. Specific NASA applications for government communications satellites include earth-orbiting data-relay satellites and microspacecraft for lunar and planetary missions. Commercial communications satellite applications include both fixed and mobile services at geostationary and nongeostationary altitudes. Specific innovations are needed in:

**MMIC, discrete, semiconductor, superconductor, or vacuum electron concepts** for components and subsystems that stress improvement in bandwidth, power efficiency, noise figure, gain, reliability, size or cost at frequencies from K-band to W-band. Advanced highly linear power amplifiers are of particular interest.

**Advanced materials, structures, and devices** (FETs, TWTs, MODFETs, or HBTs) whose improved noise, power efficiency, or frequency response will enhance the performance of communications systems components or systems.

**Antenna configurations** for producing multiple, scanned, transmitting or receiving beams from a single antenna array. Direct radiating arrays and array feeds; novel design concepts for enhancing gain, bandwidth, or functional capability; analog, digital and optical beam-forming; and integrated optoelectronic approaches all are of interest.

**Packaging and integration** of MMIC and/or photonic devices; advanced techniques, components, and designs in phased-array antenna systems. Interests include multi-chip packaging, optical-fiber hermetic feed-throughs, and device characterization technologies including characterization techniques and test structures.

**System-level circuit development.** Methods, processes, and techniques wherein power-processing, interface support, and control circuitry are co-located with an RF MMIC at the radiating element of a phased-array antenna system.


**References:**

Simons, R.N., "Optical Control of Microwave Devices." Artech House, Inc., 1990. A91-17719

Leonard, R.F., and Romonafsky, R.R., Microwave Integrated for Space Applications." Presented at the Technology 2000 Conference, Washington, D.C., November 1990. AVAIL:CASI

Wilson, J.D., Limburg, H.C., Davis, J.A., et al., "A High-Efficiency Ferruleless Coupled-Cavity Traveling-Wave Tube with Phase-Adjusted Taper," IEEE Transactions on Electron Devices, Vol.37, No. 12 (December 1990), 2638-2643. AVAIL:AIAA

Curren, A., Dayton, J., Palmer, R., et.al., " A High Efficiency KA-Band TWTA for the Cassini Mission," International Electron Devices Meeting, Washington D.C., Dec. 9-11, 1991. A92-38163


## 14.05 Digital Systems for Satellite Communications

Center: LeRC

In support of NASA's program for commercial satellite communications, advanced digital, optical, and super-conductor-based products are invited that support fault tolerant information switching and processing, autonomous network control, advanced modulation and coding, and video data compression. Innovations are requested in the following areas:

- Timing acquisition, tracking methodology, simulation, and modem development for bit-synchronous 2 Mbps MF-TDMA uplink access technique.
- Coding analysis and hardware development of a time-shared codec for a space-based destination directed packet switch.
- Autonomous network management and control.
- Digital chip or chip set of 50 Mbps burst modulators and demodulators.
- Superconductor-based products used to develop high-speed digital signal processing components, such as A/D, D/A, digital filtering, and memory.
- Video data compression techniques, both lossless and lossy, that achieve significant bit rate reductions while preserving high image quality, particularly transmission of high-resolution video and high-rate (e.g. 1000 fps) video.
- Digital video cameras supporting high-resolution, high-frame rate systems with a selection of either full-motion, high-resolution(e.g., 2000 x 2000 pixels) video or lower resolution, high-rate video (e.g., 1000 frames/sec.), color or monochrome.


**References:**

Ivancic, W.D., Shalkhauser, M.J. Bobinsky, E.A., Soni, N.J., Quitana, J.A., Kim, H., Wagner, P., Vanderaar, M., "Destination Directed Packet Switch Architecture for a Geostationary Communication Satellite Network" IAF-92-0413, August, 1992. A92-55793

"Space Communications Technology Conference: Onboard Processing and Switching," NASA, Cleveland, Ohio, Nov. 12-14, 1991. NASA-CP-3132. N92-14202

Hartz, W.G., Alexovich, R.E., and Neustadter, M.S., "Data Compression Techniques Applied to High Resolution High Frame Rate Video Technology," NASA Contractor Report CR 4263, NAS3-24564, Dec. 1989. N90-14452


## 14.06 High Data Rate Transfer Modes for Satellite and Hybrid Networks

Center: HQ

High data rate (150 Mbs/s) (HDR) terrestrial networks are becoming widely used while HDR satellite links are being designed to become part of the "Global Communications Network." While the asynchronous transfer mode (ATM) is the transfer mode of choice for HDR terrestrial terminals, similar advances and standardizations are needed for HDR satellite and hybrid (terrestrial combined with satellite) communication networks.

Innovative concepts, designs, and implementations are solicited to achieve high-speed packet switching in satellite and hybrid communication systems. ATM or alternative modes with similar high-speed performance must be explicitly designed, tested, and evaluated. Proposals may be submitted for an entire system or for a particular component. The offeror must describe a hardware or software implementation of the system and/or component, a design and test plan, and a performance evaluation plan. Innovative concepts are sought which can reduce the cost of such high-speed packet switching systems for hybrid networks. The following is a list of components of special interest:

- High reliability ATM switches for HDR satellites.
- Systems providing ATM-like performance with graceful degradation for satellite systems.
- High-speed transfer modes capable of interfacing with ATM terrestrial networks.
- Space-qualified hardware implementations of ATM or alternative high-speed packet switches.

**References:**

"Advances in Satellite Communications Networking and Applications I," Special Issue of the IEEE Journal on Selected Areas in Communications, February 1992. ISSN 0733-8716

Advances in Satellite Communications Networking and Applications II," Special Issue of the IEEE Journal on Selected Areas in Communications, February 1992. ISSN 0733-8716

"Large Scale ATM Switching Systems for B-ISDN," Special Issue of the IEEE Journal on Selected Areas in Communications, October 1991. ISSN 0733-8716

## 14.07 Superconducting Microwave and Millimeter Wave Components and Technology

Center: JPL

High-temperature superconductor (HTS) technology has potential benefits to future microwave and millimeter wave telecommunications systems in terms of electrical performance, size, power, and cost. Significant decreases in circuit losses for HTS compared to normal metals have been demonstrated at liquid nitrogen temperatures (77 K). This has led to construction of some simple Josephson-junction and three-terminal devices that utilize high-temperature superconductors. Novel systems and component approaches are needed that will provide performance improvements or unique advantages over existing non-superconducting alternative technologies. Taking advantage of systems already requiring cooling or showing that the refrigeration system can have minimum impact on the overall telecommunications system will be necessary for eventual insertion of this technology. Innovations are solicited in microwave and millimeter wave devices and subsystems capable of demonstrating such advantages in ground and/or space communications systems. Possible areas of investigation include:

- Practical antenna concepts, including arrays, frequency-selective surfaces, and beam-forming networks.
- Microwave and millimeter wave HTS active devices.
- Integrated analog and digital circuits/subsystems.
- Medium to high RF power HTS applications (amplifier circuits, feed networks, transmit antennas, high Q resonators).
- Three-dimensional HTS structures and overlays (i.e. waveguide and cavity-type resonators, striplines, cavity backed coplanar waveguides).
- Packaging technology for HTS components including electromagnetic models for predicting the effect of the package on performance of the device.
- Low-noise oscillators, including ultra-stable references or tunable oscillators.
- Compact HTS circuitry and cross-talk between lines.
- HTS variable attenuators, isolators, dividers.

**References:**

Papers presented at the 1990 Applied Superconductivity Conference reported in IEEE Trans. Magn., Vol. 27, March 1991. A91-36027

Papers on applications of superconductivity in Proc. IEEE, Vol. 77, August 1989.

Special issue on microwave applications of superconductivity, IEEE Trans. Microwave Theory Tech., Vol 39, September 1991. ISSN: 0018-9480

## 14.08 TCMS Wireless Information Network

Center: KSC

Test, control, and monitor system (TCMS) operation and maintenance (O&M) personnel will be thinly spread across several different locations. To perform their activities, TCMS O&M personnel will require access to the main information systems.

One possible solution would be to develop a system-level approach that would access the existing stationary data systems via a self-contained, highly portable computer (laptop or notebook type). This kind of wireless connection system would provide TCMS O&M personnel with:

- A remote real-time access to all of the various necessary data systems from the different areas where TCMS equipment is located.

- A substantial reduction in database update time from that of manual data recording systems.

- A substantial reduction in the setup time required to troubleshoot and make a repair on TCMS equipment. Wireless access would eliminate the need to carry paper based procedures, technical guides and or any other mandatory forms.

- A way to further shorten response times and possibly reduce the number of personnel required to respond to a service call.

This last item is especially important when considering the fact that TCMS O&M manpower availability is considerably below that which is expected to be required.

**References:**

Buehler, D.P., McDonnell Douglas Space System Company, Test, Control, and Monitor System (TCMS) Operations and Maintenance Philosophy, 1992. TS-TCMS-92001

MacFarlane, C.K., McDonnell Douglas Space System Company, Test, Control, and Monitor System (TCMS) Operations Plan, 1993. TS-TCMS-92002

Buehler, D.P., McDonnell Douglas Space System Company and Lougheed, M.J., Test, Control, and Monitor System (TCMS) Maintenance Plan, 1993. TS-TCMS-92003

## 14.09 High-Resolution Microwave Survey

Center: ARC

NASA is conducting R&D in conjunction with the High-Resolution Microwave Survey (HRMS). The project is carrying out an automated search for signals produced by extraterrestrial technology, using the largest existing antennas with 10 million channel radio frequency spectrometers. Current signal analysis equipment is capable of detecting, in real-time, signals with a strength of 70 dB below the noise in the spectrometer bandwidth with a low probability of false alarm. The automated observing system is also able to partially mitigate the effects of radio frequency interference (RFI) produced by terrestrial, airborne, and satellite transmitters. Areas needing innovation beyond the current system design are:

**Wideband, high-resolution (~1 Hz) radio frequency spectrometer** with 100 to 1000 million channels.

**A real-time scheduler for antenna control** that can operate in both interactive and automatic modes and use a changing data base (RFI, available equipment, star catalog).

**High-speed custom, VLSI chips** (efficient signal analysis algorithms realized in hardware) embedded in hardware systems for use in constant frequency and/or drifting continuous wave and low-duty-cycle pulsed signal detection in a low signal-to-noise environment.

**Advanced signal processing techniques** for the detection of complex unknown signal types.

**Hardware and software system** to identify both RFI of terrestrial origin and known radio astronomy sources and to allow for their rejection.

**High-speed, wide-bandwidth, high-density data storage media** capable of handling 100 to 1000 million bytes per second.

**References:**

Cullers, D.K., Linscott, Ivan R., and Oliver, Bernard M., "Signal Processing in SETI," Communications of the ACM, Vol. 28, No. 11, pp.1151-1163 (Nov. 1985), and Computer, Vol. 18, No. 11 (ISSN 0018-9162), pp. 37-47, Nov. 1985, ACM/IEEE-CS Joint Special Issue. A86-18540

Duluk, J.F., Linscott, I.R., Peterson, A.M., Burr, J., Ekroot, B., and Twicken, J., "VLSI Processors for Signal Detection in SETI," Acta Astronautica, Vol. 19, No.11: 927-932 (1989). A87-16126

Murray, B., Gulkis, S., and Edelson, R.E., "Extraterrestrial Intelligence: An Observational Approach," Science, Vol. 199, 485-492, (Feb. 3, 1978). A78-22524

Seeger, C.L. and Martin, Anthony R., (guest editors), "SETI: The Search for Extraterrestrial Intelligence," Acta Astronautica, Special Issue Vol. 19, No. 11 (1989). ISSN 0094-5765

## 14.10 Low-Cost, Ka-Band Ground Terminals

Center: HQ/LeRC

The Advanced Communications Technology Satellite (ACTS) currently under development uses time-division multiple accessing (TDMA) together with on-board switching and multiple, narrow, hopping-beam antennas to route communications traffic among a network of very-small-aperture terminal (VSAT) users. These 1.2 m and 2.4 m VSAT terminals are already under development. However, the spacecraft also incorporates a wide band (900 MHz) microwave switch mode (MSM) of operation. This MSM mode is a "bent pipe" mode that can support a wide variety of multiple access and modulation schemes. Innovations are needed to develop low-cost, low-data-rate (1.2, 2.4, 4.8, 9.6, 16 and 19.2 kbps) transmit and receive terminals that will operate in MSM mode of the spacecraft. Proposals may be submitted for entire terminals or for portions of one and for antennas for small satellites. Portable ground terminals are high in priority. Of particular significance are innovative concepts that can reduce cost, facilitating their transition to the market place.

Offerors are advised not to submit proposals that suggest design or development based on well-known or conventional devices obtainable through normal specification procurements. Of interest in this solicitation are the following:

- 30 GHz power amplifiers for use in the ground terminal with power outputs up to 2 watts.
- Reflector antennas with aperture diameter of less than 0.6 meters.
- Flat passive arrays with transmit apertures at 30 GHz and receive apertures at 20 GHz.
- Multiple-stage MMIC upconverters from the 70 MHz Band to the 30 GHz band.
- MMIC downconverters from 20 GHz to the 70 MHz band.
- VOCODERS to enable telephone operation at the lower bit rates.
- Channel Codecs for use at the lower bit rates.
- Low-rate modems with 70 MHz IF.
- Innovative multiple accessing schemes for simultaneous wide and narrow band users.
- High-performance, reliable, low-cost, small, flat, phased-array, Ka-band antennas and supporting MMICs.
- Small antennas using high-temperature superconducting materials.

**References:**

Proceedings of IEEE Global Communications Conference, GLOBECOM '92.

SPIE Conference, Applications of Ka-Band MMIC Technology for an Orbiter-ACTS Communications Experiment, Orlando, FL, 1990.

Special Issue on Microwave Applications of Superconductivity, IEEE Transactions, Microwave Theory, Technical Volume 39, September 1991.

Experiments Applications Guide, Lewis Research Center, Cleveland, Ohio. January 1990 Advanced Communications Technology Satellite (ACTS), National Aeronautics and Space Administration, NASA TM-100265 (Revised), ACTS Publication 101 (revised).

## 15.00 Materials Processing, Micro-Gravity, and Commercial Applications in Space

### 15.01 Materials Science
Center: MSFC

Materials research and development has always been hindered by gravity-induced disturbances and convection currents. In advance of potential space flight demonstrations, NASA provides access and assistance to outside investigators for materials studies and applications to exploit the advantages of microgravity. Innovations are sought for the following areas:

**Materials:**

- Electronic materials, semiconductors, and solid-state detectors with improved, controlled crystal growth for scientific and commercial applications.

- Metallic alloys with improved grain structures by directional solidification and processing involving supercooling and undercooling states.

- Glasses, ceramics, and optical fibers made by containerless processing to eliminate impurities, to control nucleation sites, and to process reactive melts.

**Equipment, Instrumentation, and Techniques:**

- Experimental methods for thermodynamic and transport property measurements in microgravity, including multiphase and complex regimes in crystallization, solute-solvent separation, phase-change and glass-transition separation.

- Processing techniques, including acoustic, electromagnetic, and electrostatic levitation; chemical vapor transport; physical vapor transport; directional solidification; float zone, edge-defined growth.

- Furnace and combustion processing for materials processing.

- Characterization of materials.

**Computational Techniques:**

- Simulation capabilities that will elucidate the interaction of transport phenomena during processing leading to microstructure and materials properties.

- Experimental design methodologies combining advanced process models, optimization techniques, and advanced controls.

- Models that could be incorporated into standard available transport codes.

**References:**

Kohl, F.L., "Microgravity Research at LeRC". NASA TM 102521, June 1990 AVAIL:CASI

Lehoczky, S.L., "Microgravity Processing of Electronic Materials", Invited paper-28 Aerospace Science Meeting, Reno, Nevada, Jan. 1990.

Nadarjah, A., Rosenberger, F., Alexander, J., "Modeling the Solution Growth of TOS in Low Gravity", J. of Crystal Growth, No. 104, pp. 218-232, 1990. A91-22152

Andrews, R.N., Szofran, F.R., Lehoczky, S.L., "Growth and Characterization of Hg1xCdxTe Alloys", J. of Crystal Growth, 1988. A89-23485

## 15.02 Microgravity Science, Engineering, and Applications Other Than Materials

Center: LeRC

The low-gravity (microgravity) environment of orbiting spacecraft eliminates buoyant currents and natural convection, simplifying some studies of heat and mass transfer but complicating many experimental, operational, and protection techniques for human-crew spacecraft.

To accommodate investigations for short-duration low-gravity science and/or definition of space flight experiments, the NASA Lewis Research Center can make its unique government research facilities available. Up to 5 seconds of low-gravity time can be obtained in drop towers; up to 20 seconds in airplane trajectories.

Innovations are sought in the following areas:

- Experiments and experimental equipment for the technology areas of energy conversion, space power systems, fluid and thermal management systems, spacecraft fire safety, and space environmental effects.

- Advanced instrumentation, sensors, and diagnostic techniques for non-perturbing measurements of fluid, thermal, and flow parameters.

- Advanced technology in furnace performance (heating and cooling techniques), methods of insulation, and variable control for microgravity experiments.

- Large-volume, high-rate data recording, storage, processing, and transmission of microgravity experiments.

- Other innovative areas such as property measurement techniques, waste product disposal systems, unique mechanical devices, sample preparation techniques, automated experiment and process control, and acceleration/vibration measurement and control.

- Techniques that can lower the cost and/or shorten the time required for the development of flight experiments.

**References:**

Law, C.K., "Combustion in Microgravity: Opportunities, Challenges, and Progress," Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. AIAA Paper 90-0120. A90-23703

Ross, Howard D., and Greenberg, Paul S., New Findings and Instrumentation from the NASA Lewis Microgravity Facilities. NASA TM 103189, May 1990. N90-26163

The Microgravity Combustion Group: "Microgravity Combustion Science: Progress, Plans, and Opportunities." NASA TM 105419, April 1992. N92-27197

## 15.03 Biotechnology: Medical and Molecular Biology Applications

Center: JSC

Microgravity provides a unique environment for new methods of processing biological materials that have medical applications or will lead to spinoffs in medicine and biotechnology. A biotechnology research facility is being planned for future manned spacecraft. This facility requires innovations in the following areas:

- New methods for culturing live human cells in bioreactors, including miniature sensors and process controllers. Methods for purification of living cells or proteins, especially using electric or magnetic fields that avoid compromises by thermal convection and sedimentation.

- Advanced protein crystal growth techniques for macro-molecular assembly of biological membranes, biopolymers, and molecular bioprocessing systems; microencapsulation of drugs and novel delivery systems; development of biocompatible materials, devices, and sensors for implantable medical applications.

- Applications of molecular biology, image and flow cytometry, and microassays for measurement of cell metabolism, immune cell functions, and cell products secreted from tissues or cultured cells.

**References:**

Morrison, Dennis R., "Suspension Cell Culture in Microgravity and Development of a Space Bioreactor," in Proceedings of the Space Bioreactor Workshop, NASA Conference Publication #2485, NTIS, Springfield, VA., 1987, pp. 1-18. N88-17169

Todd, P., et al., "Cell Bioprocessing in Space: Applications of Analytical Cytology," The Physiologist Vol. 31 (No. 1, Suppl.): pp. S-52 - S-55, 1988. A88-54028

NASA Technical Memorandum 4191: Microgravity Sciences and Applications Program Tasks, 1989, avail. NTIS, May 1990. N90-20252

## 15.04 Automated, Noninvasive, Transcutaneous Assay Method for Blood-Borne Agents

Center: HQ

An automated, noninvasive, transcutaneous method for assaying drugs and biological regulatory factors in the blood of rodent test subjects is needed to enable discovery research and pharmaceutical product testing to proceed for 30 to 90 days aboard unmanned free flyers and other space vehicles. Research conducted by NASA and others has shown that animals and humans exposed to microgravity experience bone demineralization, muscular atrophy, cardiovascular deconditioning, decreased red blood cell count, depressed hormone secretion, decreased immune response, neurovestibular disturbances, and other biological changes. These changes can be used as models in product testing, developing, and discovery research on aging, osteoporosis, anemia, muscle atrophy, hormone secretion disorders, and immune system impairment, as well as other disease states found on Earth.

This subtopic solicits automated, noninvasive, transcutaneous techniques, including small, self-contained, implantable biosensors and/or micromechanical spectrometers-on-a-chip that can detect drugs and/or biological markers in unrestrained rodents housed in extended duration, small-animal life-support units. The instrumentation must be reconfigurable to provide the broadest applications as well as high specificity. Ideally, the techniques will be flexible enough to be tailored to meet the particular needs of a wide variety of experiments. Data acquisition and storage instrumentation must be compact, self-calibrating, and user-friendly.

**References:**

Bonting, S.L., Kishiyama, J.S., Arno, R.D., "Facilities for Animal Research in Space with Special Reference to Space Station Freedom," Intersociety Conference on Environmental Systems, 20th Williamsburg, VA, July 9-12, 1990, 779-800. A90-49355

Jakubowicz, R.F., "Instrumentation for Biomedical Clinical Chemistry: Clinical Analysis Capabilities for NASA's Space Station," Proceedings of the Annual International Conference for Engineering in Medicine and Biology Society, cit, 1797-1798.

Wise, D.L., Wingard, Jr., B.L., eds. Biosensors with Fiber Optics, Human Press 1991, 416 pp. ISBN 0894603190X

McKinley, B.A., "Development of a Clinical Chemistry Analyzer for Medical Laboratory Diagnosis at the NASA International Space Station Freedom," JJCLA, Vol. 15, No. 1, 1990.

## 15.05 Autonomous Support of Living Cells in Space

Center: HQ

Autonomous devices capable of supporting living cells for periods of time ranging from seven to ninety days are required for use on the Shuttle, COMET/WESTAR, and advanced space missions to enable the pilot production of cell cultures, cell products, CELSS subsystem tests, development of cellular/microorganism-based physiological testing, and modeling regimes in the microgravity environment.

This subtopic solicits the development of innovative, light-weight, modular autonomous cell-support units that are generic in character in the sense that the technical capabilities embodied in the device will foster a wide spectrum of cell culture activities including plant and animal cell culture, study of microorganism colonies, introduction of a variety of reagents to cultured cells at appropriate times, mechanisms for fixing cell cultures when required, monitoring of cell novel electro-optical/videographic/photographic methods.

Offerers should also consider design characteristics that will permit the units to be readily deployed in: small versions for COMET/WESTAR, large versions for STS lockers, and "ganged" versions.

**References:**

MacElroy, E.D., Greenwalt, S., "Controlled Ecological Life Support Systems," NASA TM 102277, March, 1990 217-252, 1988. N91-31775

Hoehn, A., Simske, S.J., Luttges, M.W., "The P-Mass: A Plant Growth Module for Autonomous Space Support on Board COMET," International Conference on Life Support and Biospherics, University of Alabama-Birmingham, February 18-20, 1992.

Saimske, S.J., Luttges, M.W., Hoehn, A., "The A-Mass: The Animal Module for Autonomous Space Support on COMET I," International Conference on Life Support and Biospherics, University of Alabama-Birmingham, February 18-20.

Cochran, W.W., "Wildlife Telemetry," In: Wildlife Management Techniques Manual, 4th Edition, S.D. Schemnitz, ed., The Wildlife Society, Washington, D.C. 1980. No. 85-23, 1985.

## 15.06 Diagnostic Equipment and Reconfigurable Containment Systems
Center: MSFC

On previous materials processing in space experiments, on-orbit sample exchanges and analyses have been limited by safety requirements and relatively short duration of all previous Shuttle-era manned missions. With the advent of extended shuttle missions, safe crew access to the contained experiment sample materials and equipment will be necessary for such activities as on-orbit maintenance, sample characterization, sample resupply, sample change-out, and experiment reconfiguration. Innovations should be reliable, light-weight, low-power, and capable of operating safely in a manned environment.

**An x-ray system** is needed to perform the on-orbit evaluation, analysis, and characterization of protein crystals.

**An ampoule-failure detector system** is required to prevent inadvertent crew contact with potentially toxic sample materials such as metal vapors. Sample materials may include the following: CdTe, HgCdTe, GaAs, PbSnTe, HgZnTe, PbBr, and $HgI_2$.

**Logistics carriers or containers** are needed that will accommodate thermal conditioning for perishable samples before launch, during ascent to a space laboratory, during descent to Earth, and on the ground immediately after landing until they can be retrieved. Units with minimum resource requirements (e.g., that required little or no power) would be ideal. Minimum weight would also aid in physical integration. Such containers that would fit within the physical limitations of two middeck lockers would greatly alleviate the demand for power and interface verification testing for sample logistics.

**References:**

NASA Office of Commercial Programs, Commercial Development Division, "Accessing Space: A Catalog of Process, Equipment, and Resources for Users", Dec. 1990.

NASA/MSFC Document JA01-001, "U.S. Users Space Station Freedom Laboratory Support Equipment/General Laboratory Support Facilities Level II Requirements Document," October 11, 1991, pp. 101-104.

NASA/MSFC Document JA55-032, "Space Station Furnace Facility Capability Requirements Document," latest revision.

NASA Technical Memorandum 4339, "Microgravity Science and Applications Bibliography" Feb. 1992. August 1990. Teledyne Brown, Colorado Springs, CO.

## 15.07 Components for a Space-Based Plant Growing Unit
Center: HQ

Plant biotechnology has experienced extraordinary success in recent years by applying new molecular biology techniques to facilitate and enhance the traditional methods used in the development of superior plant materials. The horizons of plant biotechnology need to be expanded to utilize the unique characteristics of the microgravity environment of space. The capability to conduct these activities in space is dependent on the development of space flight hardware that provides the environmental conditions required to effectively support plant growth. Development of plant growth units for space requires innovations in the following technology areas:

**Lighting systems** based on solid-state light-emitting materials that have small volume and mass characteristics, emit light at wavelengths used most effectively by plants, and provide high electrical conversion efficiencies.

**Devices** having high reliability, low power consumption, and small mass for the measurement of gaseous $CO_2$ at concentrations found in plant growing units (0.03 to 0.5 percent of total atmospheric gas composition).

For the measurement of atmospheric contamination gases such as ethylene, that would have a deleterious impact on plant growth, at concentrations found in plant growth units (0 to 50 ppb of total atmospheric gas composition).

For the measurement of electrical conductivity of nutrient solutions.

**References:**

Halstead, T.W., "Plants in Space," Annual Rev. Plant Physiol., 38: 317-345, 1987. ISSN 0066-4294

Baumgardt, B.R., and Martin, M.A., eds., "Agricultural Biotechnology; Issues and Choices," Purdue University Agric. Exp. Sta., 1991.

Boylan, M.T., and Quail, P.H., "Oat Phytochrome is Biologically Active in Transgenic Tomatoes," Plant Cell 1: 765-773, 1989. ISSN 1040-4651

Barta, D.J., Tibbitts, T.W., Bula, R.J., and Morrow, R.C., "Evaluation of Light Emitting Diode Characteristics for a Space-Based Plant Irradiation Source," Advances in Space Research, 12, (5): 141-149, 1992. A92-20986

# FORM 9.A - PROPOSAL COVER

| | 4 DIGIT SUBTOPIC NUMBER | LAST 4 DIGITS OF FIRM PHONE NO. | CHANGE LETTER | |
|---|---|---|---|---|
| PROPOSAL NUMBER 93-1 | __.__ | ____ | __ | (Instructions on Reverse Side) |

SUBTOPIC TITLE ____________________

PROJECT TITLE ____________________

____________________

FIRM NAME ____________________

MAIL ADDRESS ____________________

CITY/STATE/ZIP ____________________

PHONE ____________________

PHASE I AMOUNT REQUESTED: $__________ DURATION: _____ MONTHS

**OFFEROR CERTIFIES THAT:**

| | YES | NO |
|---|---|---|
| 1. As defined in Section 2 of the Solicitation, this firm qualifies as a: | | |
| 1.1 Small business concern | ☐ | ☐ |
| 1.2 Socially and economically disadvantaged small business concern | ☐ | ☐ |
| 1.3 Women-owned small business | ☐ | ☐ |
| 2. A minimum of two-thirds of the research and/or analytical effort for this project will be carried out within the firm if an award is made. | ☐ | ☐ |
| 3. The primary employment of the principal investigator will be with this firm at the time of award and during the conduct of the research. | ☐ | ☐ |
| 4. Proposals of similar content have (indicate Yes) or have not (indicate No) been submitted to another agency. | ☐ | ☐ |
| 5. The firm has (indicate Yes) or has not (indicate No) received federal funds for substantially similar work. | ☐ | ☐ |

**ENDORSEMENTS:**

| | Principal Investigator | | Corporate/Business Official |
|---|---|---|---|
| Typed Name | __________ | | __________ |
| Title | __________ | | __________ |
| Signature | __________ | Signature | __________ |
| Date | __________ | Date | __________ |

## PROPRIETARY NOTICE (If Applicable, See Sections 5.4.1 & 5.5)

*NOTICE:* For any purpose other than to evaluate the proposal, this data shall not be disclosed outside the government and shall not be duplicated, used, or disclosed in whole or in part, provided that if a funding agreement is awarded to this proposer as a result of or in connection with the submission of these data, the Government shall have the right to duplicate, use, or disclose the data to the extent provided in the funding agreement. This restriction does not limit the Government's right to use information contained in the data if it is obtained from another source without restriction. The data subject to this restriction are contained in pages ______ of this proposal.

# INSTRUCTIONS FOR COMPLETING PROPOSAL COVER

**General**--Complete Form 9.A and sign manually. Make five photocopies to use as the cover sheet for each copy of your proposal. Submit the original copy separately. (See Sections 3.2, 3.3, 3.4 and 6.1 for further instructions) If additional copies of the blank form are needed, the offeror should photocopy this one.

1. **Proposal Number--**This number does not change even if the firm gets a new phone number. Complete the proposal number as follows:

   a. Enter the four-digit subtopic number.
   b. Enter the last four digits of your firm's telephone number.
   c. If you are submitting different proposals under the same subtopic, enter a change letter as appropriate to differentiate proposal numbers.

   **Example I:** A company with telephone number 273-8126 submits one proposal to subtopic 06.03. The proposal number is **06.03-8126.**

   **Example II:** A company with telephone number 392-4826 submits three different proposals to subtopic 11.03. The proposal numbers are: **11.03-4826**
   **11.03-4826A**
   **11.03-4826B**

   Enter the proposal number on Forms 9.B and 9.C.

2. **Subtopic Title:** Enter the title of the subtopic that this proposal will address. Use abbreviations as needed.

3. **Project Title:** Enter a brief, descriptive title using no more than 80 keystrokes (characters and spaces). **Do not** use the subtopic title. Avoid words like "development" and "study".

4. **Firm Name:** Enter the full name of the company submitting the proposal. If a joint venture, list the company chosen to negotiate and receive contracts. If the name exceeds 40 keystrokes, please abbreviate.

5. **Address:** Enter address where mail is received.
   **State:** Enter 2-letter designation (example Maine: ME)
   **Zip Code:** Enter 5- or 9-digit code
   **Phone:** Enter general phone number of the firm.

6. **Phase I: Amount Requested:** Enter proposal amount from Budget Summary. The amount requested should not exceed $70,000. Round to nearest dollar. **Do not** enter cents.
   **Duration:** Enter the proposed duration in months. If the proposed duration is other than 6 months, be sure to discuss the reason in the text of the proposal.

7. **Certifications:** Enter **Y** for yes or **N** for no in the appropriate boxes.

8. **Endorsements:** The proposal should be signed by the proposed **Principal Investigator and an official of the firm** qualified to make a contractual commitment on behalf of the firm. The PI and the Corporate Official may be the same person. The copy of the cover sheet submitted as the single original should have original signatures.

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   **11.03-4826B**

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# FORM 9.A - PROPOSAL COVER

| | | 4 DIGIT SUBTOPIC NUMBER | LAST 4 DIGITS OF FIRM PHONE NO. | CHANGE LETTER | |
|---|---|---|---|---|---|
| PROPOSAL NUMBER | 93-1 | __.__ | ____ | __ | (Instructions on Reverse Side) |

SUBTOPIC TITLE ______________________________

PROJECT TITLE ______________________________

______________________________

FIRM NAME ______________________________

MAIL ADDRESS ______________________________

CITY/STATE/ZIP ______________________________

PHONE ______________________________

PHASE I AMOUNT REQUESTED: $__________ DURATION: ________ MONTHS

**OFFEROR CERTIFIES THAT:**

| | YES | NO |
|---|---|---|
| 1. As defined in Section 2 of the Solicitation, this firm qualifies as a: | | |
| 1.1 Small business concern | ☐ | ☐ |
| 1.2 Socially and economically disadvantaged small business concern | ☐ | ☐ |
| 1.3 Women-owned small business | ☐ | ☐ |
| 2. A minimum of two-thirds of the research and/or analytical effort for this project will be carried out within the firm if an award is made. | ☐ | ☐ |
| 3. The primary employment of the principal investigator will be with this firm at the time of award and during the conduct of the research. | ☐ | ☐ |
| 4. Proposals of similar content have (indicate Yes) or have not (indicate No) been submitted to another agency. | ☐ | ☐ |
| 5. The firm has (indicate Yes) or has not (indicate No) received federal funds for substantially similar work. | ☐ | ☐ |

| ENDORSEMENTS: | Principal Investigator | Corporate/Business Official |
|---|---|---|
| Typed Name | ____________ | ____________ |
| Title | ____________ | ____________ |
| Signature | ____________ | Signature ____________ |
| Date | ____________ | Date ____________ |

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# INSTRUCTIONS FOR COMPLETING FORM 9.B

**General:**

To facilitate proposal processing, NASA may employ automated optical devices to record proposal information. Towards this end, it is required that the Proposal Cover sheet (Form 9.A) and the Project Summary (Form 9.B) be typed without using a mono-spaced typestyle such as Courier, Letter Gothic or Prestige, Pica or Elite in 10 or 12 characters per inch (pitch) or 12 point.

1. **Proposal Number:** Enter the same proposal number as shown on your Proposal Cover sheet.
2. **Project Title:** Enter the same title as shown on your Proposal Cover sheet.
3. **Technical Abstract:** Provide a summary of 200 words or less of your proposed project. The abstract must not contain proprietary information and must describe the proposed innovation. (See Section 3.4.2.)
4. **Potential Commercial Applications:** Summarize the commercial potential of the project assuming the goals of the proposed research or R&D are achieved.
5. **Key Words:** Provide no more than 8 key words descriptive of the project and useful in identifying the technology, research area, or application of the proposed effort.
6. **Name and Address of the Firm:** Enter firm name and mailing address as shown on the Proposal Cover sheet.
7. **Principal Investigator:** Enter name of Principal Investigator as shown on the Proposal Cover sheet.

# FORM 9.B - PROJECT SUMMARY

| | | 4 DIGIT SUBTOPIC NUMBER | LAST 4 DIGITS OF FIRM PHONE NO. | CHANGE LETTER | **(Instructions on Reverse Side)** |
|---|---|---|---|---|---|
| PROPOSAL NUMBER | 93-1 | __.__ | ____ | _ | AMOUNT REQUESTED $ ____________ |

TITLE OF PROJECT

TECHNICAL ABSTRACT (LIMIT 200 WORDS)

POTENTIAL COMMERCIAL APPLICATIONS

KEY WORDS
(LIMIT 8)

NAME AND ADDRESS OF OFFEROR (Firm Name, Mail Address, City/State/Zip)

PRINCIPAL INVESTIGATOR

# FORM 9.B - PROJECT SUMMARY

| | | 4 DIGIT SUBTOPIC NUMBER | LAST 4 DIGITS OF FIRM PHONE NO. | CHANGE LETTER | (Instructions on Reverse Side) |
|---|---|---|---|---|---|
| PROPOSAL NUMBER | 93-1 | __.__ | ____ | _ | AMOUNT REQUESTED $ ________ |

TITLE OF PROJECT

TECHNICAL ABSTRACT (LIMIT 200 WORDS)

POTENTIAL COMMERCIAL APPLICATIONS

KEY WORDS
(LIMIT 8)

NAME AND ADDRESS OF OFFEROR (Firm Name, Mail Address, City/State/Zip)

PRINCIPAL INVESTIGATOR

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4. **Firm Name:** Enter the full name of the company submitting the proposal. If a joint venture, use the name of the entity chosen to negotiate and receive contracts. If the name exceeds 40 keystrokes, please abbreviate.

5. **Address:** Enter address where mail is received.
   **State:** Enter two-letter designation (example Maine: ME)
   **Zip Code:** Enter five- or nine-digit code
   **Phone:** Enter general phone number of the firm.

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# FORM 9.C - SBIR PROPOSAL SUMMARY BUDGET

(Instructions on Reverse Side)

PRINCIPAL INVESTIGATOR:

FIRM:

PROPOSAL NUMBER:

AMOUNT REQUESTED:

DIRECT LABOR:
Category

Hours    Rate    Cost $

TOTAL DIRECT LABOR: (1) $

OVERHEAD RATE _____% of Total Direct Labor

OVERHEAD COST: (2) $

OTHER DIRECT COSTS:
Category

Cost $

TOTAL OTHER DIRECT COSTS: (3) $

(1)+(2)+(3)=(4)

SUBTOTAL: (4) $

G&A RATE ____% of Subtotal

G&A COSTS: (5) $

(4)+(5)=(6)

TOTAL COSTS: (6) $

ADD PROFIT or SUBTRACT COST SHARING

PROFIT/COST SHARING: (7) $

(6)+(7)=(8)

AMOUNT REQUESTED: (8) $

**THIS PROPOSAL IS SUBMITTED IN RESPONSE TO NASA SBIR PROGRAM SOLICITATION 93-1 AND REFLECTS OUR BEST ESTIMATES AS OF THIS DATE:**

TYPED NAME AND TITLE:

SIGNATURE:

DATE:

# FORM 9.C - SBIR PROPOSAL SUMMARY BUDGET

(Instructions on Reverse Side)

PRINCIPAL INVESTIGATOR: PROPOSAL NUMBER:

FIRM: AMOUNT REQUESTED:

DIRECT LABOR:

| Category | Hours | Rate | Cost |
|---|---|---|---|
| | | | $ |

TOTAL DIRECT LABOR: (1) $

OVERHEAD RATE _____% of Total Direct Labor

OVERHEAD COST: (2) $

OTHER DIRECT COSTS:

| Category | Cost |
|---|---|
| | $ |

TOTAL OTHER DIRECT COSTS: (3) $

(1)+(2)+(3)=(4)

SUBTOTAL: (4) $

G&A RATE ____% of Subtotal

G&A COSTS: (5) $

(4)+(5)=(6)

TOTAL COSTS: (6) $

ADD PROFIT or SUBTRACT COST SHARING

PROFIT/COST SHARING: (7) $

(6)+(7)=(8)

AMOUNT REQUESTED: (8) $

**THIS PROPOSAL IS SUBMITTED IN RESPONSE TO NASA SBIR PROGRAM SOLICITATION 93-1 AND REFLECTS OUR BEST ESTIMATES AS OF THIS DATE:**

TYPED NAME AND TITLE:

SIGNATURE:

DATE:

PROPOSAL PAGE NO.

# INSTRUCTIONS FOR SBIR PROPOSAL SUMMARY BUDGET

By using this form, the offeror submits to the Government a pricing proposal of estimated costs with detailed information for each cost element, consistent with the offeror's cost accounting system. (See Section 3.6 for further information)

This summary does not eliminate the need to fully document and justify the amounts requested in each category. Such documentation should be contained, as appropriate, on a budget explanation page immediately following the budget in the proposal. (See below for discussion on various categories)

1. **Direct Labor**--Enter labor categories (e.g., principal investigator, laboratory assistant, administrative staff), rates of pay and the hours for each labor category.

2. **Overhead**--Specify current rate(s) and base(s). Use current rate(s) negotiated with the cognizant federal negotiating agency, if available. If no rate(s) has(have) been negotiated, a reasonable indirect cost (overhead) rate(s) may be requested for Phase I that will be subject to approval by NASA. If a current negotiated rate(s) is(are) not available for Phase II, NASA will negotiate an approved rate(s) with the offeror. The offeror may use whatever number and types of overhead rates that are in accordance with the firm's accounting system and approved by the cognizant federal negotiating agency, if available. Multiply Direct Labor by the Overhead Rate to determine the Overhead Cost.

3. **Other Direct Costs**

   a. *Materials and Supplies:* Indicate types required and estimate costs.
   b. *Documentation Costs or Page Charges:* Estimate cost of preparing and publishing project results.
   c. *Subcontracts:* Include a completed budget--including hours and rates--and justify details. (See Sections 3.5, Part 9 and 5.12 for further information)
   d. *Consultant Services:* Indicate name, daily compensation, and estimated days of service. (See Section 3.5, Part 9 for further information.)
   e. *Computer Services:* Computer equipment leasing is included here.
   f. *Equipment:* List each item of permanent equipment to be purchased, its price, and explain its relation to the project.

   List all other direct costs that are not otherwise included in the categories described above.

4. **Subtotal**--Sum of (1) Total Direct Labor, (2) Overhead and (3) Other Direct Costs.

5. **General and Administrative** (G&A)--Specify current rate and base. Use current rate negotiated with the cognizant federal negotiating agency, if available. If no rate has been negotiated, a reasonable indirect cost (overhead) rate may be requested for Phase I that will be subject to approval by NASA. If a current negotiated rate is not available for Phase II, NASA will negotiate an approved rate with the offeror. Multiply (4) Total Direct Cost by the G&A Rate to determine G&A Cost.

6. **Profit**--See Sections 3.6.4 and 5.9.

7. **Amount Requested**--This should exclude any cost-sharing and not exceed $70,000.

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